University of Reading

Challenge and change: a history of the Nuffield A-level Physics Project

Book

Updated Version

Final version, published internally

Fuller, K. D. and Malvern, D. D. (2010) Challenge and change: a history of the Nuffield A-level Physics Project. Institute of Education, University of Reading, Reading, pp278. (Unpublished) Available at http://centaur.reading.ac.uk/7534/

It is advisable to refer to the publisher's version if you intend to cite from the work. See Guidance on citing.

Publisher: Institute of Education, University of Reading

All outputs in CentAUR are protected by Intellectual Property Rights law, including copyright law. Copyright and IPR is retained by the creators or other copyright holders. Terms and conditions for use of this material are defined in the End User Agreement.

www.reading.ac.uk/centaur

University of Reading

CentAUR

Central Archive at the University of Reading

Reading's research outputs online

Challenge and Change

A History of the Nuffield A-level Physics project

Keith Fuller and David Malvern

Challenge and Change

A History of the Nuffield A-level Physics Project

Keith Fuller and David Malvern

Contents

List of Tables Page

List of Figures

List of Abbreviations

AEB	Associated Examining Board
APU	Assessment and Performance Unit
ASE	Association for Science Education
AWST	Association of Women Science Teachers
BTEC	Business and Technical Education Council
DES	Department of Education and Science
FRS	Fellow of the Royal Society
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
CSE	Certificate of Secondary Education
HMI	Her Majesty's Inspectorate
HMSO	Her Majesty's Stationary Office
INSET	In-Service Education and Training
IPPS	Institute of Physics and Physical Society
JMB	Joint Matriculation Board
LEA	Local Education Authority
NCC	National Curriculum Council
NCCT	Nuffield-Chelsea Curriculum Trust
NCVQ	National Council for Vocational Qualifications
NFCPC	Nuffield Foundation Curriculum Projects Centre
NFSTP	Nuffield Foundation Science Teaching Project
NOB	Nuffield O-level Biology Project
NOC	Nuffield O-level Chemistry Project
NOP	Nuffield O-level Physics Project
NAB	Nuffield A-level Biology Project

NAC	Nuffield A-level Chemistry Project
NAP	Nuffield A-level Physics Project
NAPS	Nuffield A-level Physical Science Project
PGCE	Postgraduate Certificate of Education
PS	Physical Science
PSSC	Physical Science Study Committee
RIC	Royal Institute of Chemistry
RNAB	Revised Nuffield A-level Biology Project
RNAC	Revised Nuffield A-level Chemistry Project
RNAP	Revised Nuffield A-level Physics Project
SCUE	Standing Conference on University Entrance
SEAC	School Examinations and Assessment Council
SEC	Secondary Examinations Council
SED	Scottish Education Department
SMA	Science Masters' Association
SMP	School Mathematics Project
SPM	Structure and Properties of Matter
SSCER	Secondary Science Curriculum Review
SSEC	Secondary School Examinations Council
TGAT	Task Group on Assessment and Testing
UGC	University Grants Committee

Acknowledgements

An overriding impression from this research has been the goodwill, cooperation and friendliness from the many people contacted for information and advice. A number of these people have given interviews and pushed their memories to the limit: Fred Archenhold, Paul Black, Lewis Elton, John Harris, Peter Kelly, John Lewis, Sir Nevill Mott, Jon Ogborn, Simon Pascoe, Mike Ridley, John Spice, Mary Waring, and Ted Wenham. Many more people have provided help by letter, telephone and personal visits: Tony Becher, Maurice Ebison, Sandy Grassie, Nick Heath, Gordon Higginson, Mary Jenkins, David Layton, Jill Nelson, Gordon van Praagh, Eric Rogers, Peter Tickle, Dick West, Cathy Wilson, Brian Woolnough and Sylvia Wynn.

Professor Kevin Keohane's blessing opened many doors, especially at the Nuffield Foundation and at the Nuffield-Chelsea Curriculum Trust, and he also read the first drafts; his comments and corrections are gratefully acknowledged. Of course, we must add the usual disclaimer: any mistakes in interpretation and content are ours and ours alone.

Gratefully acknowledged is the help received from John Hayes, and from the staff at the University of Reading Education Library and at the King's College London (KQC) Library. David Crowhurst was most helpful in providing access to the NFSTP files at King’s College (KQC).

Dedication

The research and its publication are dedicated to our families: Melanie & Tristan and Sue & Esther.

INTRODUCTION
Physics Curriculum History

The novelist Bruce Chatwin came to the conclusion, just before his unexpected death, that: "....history is always our guide for the future, and is always full of capricious surprises. The future is a dead land because it does not yet exist."[1] This book is an history of the birth, growth and continuation of the Nuffield A-level Physics project (NAP), set within the wider context of the Nuffield Foundation's attempts to reform the schools' A-level science curriculum in England, Wales and Northern Ireland. It contains a number of capricious events: the unexpected death of the first Nuffield O-level Physics (NOP) Organizer, Donald McGill, and the opportune appointment of the enigmatic personality, Professor Eric Rogers; the last minute changes made to the A-level programme by Sir Ronald Nyholm that resulted in the birth of NAP; and the traumatic resignation of Dick Long, the first NAP Organizer. But not all of the historical events recorded here are so transient. Most are the consequences of very careful thought and action. Presseisen has called all such events 'historical underpinnings', and believes that documenting their detailed narrative and biography may lead to 'unlearned lessons', which may even throw some light on, and enliven, the 'dead land future'.[2]

William Reid, formerly of the University of Birmingham, in his article *Curriculum theory and curriculum change: What can we learn from history?* emphasises that recording the fundamental details of social and institutional change, as it actually occurred, should help us clarify such questions as "....how it comes about, and how can it be managed and controlled."[3] In this book, for example, we show how, in managing its curriculum developments, the Nuffield Foundation quite quickly realized that the Nuffield Foundation Science Teaching Project (NFSTP) should exist as a separate entity, away from Nuffield Lodge. Their experiment in curriculum development rapidly became a complex, time-consuming and expensive enterprise, and the Trustees were keen to institutionalize the science projects in a university department and so divest themselves of the day-to-day running of the NFSTP. In time this decision resulted in the formation of a curriculum renewal institution called the Nuffield-Chelsea Curriculum Trust (NCCT) which in turn led to the Nuffield Curriculum

Centre. Key personnel in the NFSTP O-and A-level projects are listed in Table 1.

TABLE 1 - KEY PERSONNEL (1964-1987)

Co-ordinators:	J.MADDOX	1964-1966.
	K.KEOHANE	1966-1979 (and onwards as Chairman NCCT).

NUFFIELD O-LEVEL PROJECTS

	Original Project Organizer(s)	Date Published	Revised Project Editors	Date Published
NUFFIELD O-LEVEL PHYSICS (NOP)	D.McGILL (1963-64) E.ROGERS(1964-67)	1966-68	E.ROGERS and E.WENHAM	1976-80
NUFFIELD O-LEVEL CHEMISTRY(NOC)	F.HALLIWELL	1966-67	R.INGLE and B.DAWSON	1974-79
NUFFIELD O-LEVEL BIOLOGY (NOB)	W.DOWDESWELL	1966-67	G.MONGER	1974-75

NUFFIELD A-LEVEL PROJECTS

NUFFIELD A-LEVEL PHYSICS (NAP)	V.LONG(1965-67) P.BLACK and J.OGBORN	1971-73	J.HARRIS	1985-86
NUFFIELD A-LEVEL CHEMISTRY(NAC)	E.COULSON	1970-71	B.STOKES	1984-85
NUFFIELD A-LEVEL PHYSICAL SCIENCE (NAPS)	J.SPICE	1972-74	--not reprinted--	
NUFFIELD A-LEVEL BIOLOGY (NAB)	P.KELLY and W.DOWDESWELL	1970-72	G.MONGER	1986-87

CONSULTATIVE COMMITTEE CHAIRMEN:

Professor MOTT(NOP), Professor NYHOLM (NOC), Professor SWANN (NOB), Professors MOTT and NYHOLM (NAPS, NAP, NAC), Professor BURNETT (NAB).

After the publication of the Nuffield A-level projects many of the people involved did not return to their seconded posts, but took up positions in university education departments.[4] Few of them, or, for that matter, few curriculum scholars at the time, concerned themselves with reflecting on the history of the projects.[5] Reid reasons that such people have been raised in other disciplines, in this case science, and that they see the past “represented as a dark age best forgotten in the search for a brighter future."[6] In any case, as Marsden notes: "It is also more difficult to capture the sense of period soon after the events have occurred, in which the historical interpreter may be one and the same person as the historical actor, and be too bound up with the issues to provide an impartial appraisal."[7]

Inevitably, the A-level Organizers and their Nuffield Foundation colleagues had to make many individual judgements which often brought them into conflict with other interested parties. Some of these decisions will be critically analysed in later chapters, but an obvious example is found in the account of the first Organizer of NAP, Dick Long, his struggle to produce courses for understanding and breadth, and the story of resistance from Universities.[8] The struggle led eventually to his resignation and a crisis in the progress of NAP. Such reflections are sometimes best forgotten by the 'historical actors'; however, in this case, they form the basis of Chapter 2.

Curriculum history researchers, in particular Goodson, McCulloch, Reid, and Taylor, have argued emphatically for historical studies to illuminate the theoretical aspects of curriculum renewals in the UK. For instance, McCulloch calls for a greater interaction between history and policy and picks up Shil's wish to unearth a 'usable past'.[9] Goodson points out that "We know very little about how the subjects and themes prescribed in schools originate, how they are promoted and re-defined, and how they metamorphose" and argues "What is needed is to build on studies of participants immersed in immediate process, to build on historical events and periods, and to develop a cumulative understanding of the historical contexts in which the contemporary curriculum is embedded."[10] Tony Edwards, Professor of Education at the University of Newcastle-upon-Tyne, also sees the value of empirical research into curriculum development, noting in his critique of Goodson's book *The Making of the Curriculum* [11]: “I share his enthusiasm for sociologically informed histories of the curriculum, his concern that there is still so little detailed empirical work, and his insistence that it is the curriculum (not management) which is the heart of schooling.”[12]

It is to contribute a study of one curriculum development project, its participants and events, and to shed light on how its themes originated and then metamorphosed, that this book was written.

Keith Fuller writes:

> "My interest in these things, however, began while I was teaching NOP and NAP at Bedales School and became aware that Bedales had nurtured Eric Rogers, both as boy and man. Rogers, in turn, had been strongly influenced by the educationalist J.H.Badley [13], and by the experimental genius of F.A.Meier[14], previous Headmasters at Bedales.
>
> Furthermore, like many teachers new to NAP, I was finding the course a challenge, both to my teaching style and to the novel course materials(see Chapter 4). In fact, I must now nail my colours to the mast - after two years, once through the whole NAP course, I joined the ranks of the converted. I had learned a great deal from teaching the course, and realised the value of many of its features, as well as some shortcomings for our particular school.
>
> In 1982, in order to complete an M.Sc. dissertation on a general review of NAP, focussing upon the financial aspects of the course, fact-finding interviews were arranged with the NAP Organizers, Paul Black and Jon Ogborn, and then with Kevin Keohane, the NFSTP Co-ordinator. Consequently, following completion of the M.Sc. degree, some further research was carried out, leading to the publication with David Malvern in 1986 of '*One Don, One Beak' - University pressure and curriculum development in the first Nuffield A-level physics project,* dealing with some of the historical events in the first NAP developments.[15]
>
> For the 1986 Institute of Physics Education Group conference on *Physics Education across the School-Higher Education Interface*, I had prepared a brief abstract of this article.[16] I was somewhat surprised at the reception by one or two people who themselves had been involved in the NFSTP. For some it may have been disturbing to be reminded that the path to NAP was not wholly smooth, and the accuracy of the account was called into question. I had my confidence in its accuracy confirmed by Wenham, Black and Keohane, but realized that the NAP project's history deserved more study.

> It was clear that it needed more than Silver's phrase, a snapshot 'raid into history' [17], and that more was needed for some people, at least, to come to terms with the past."

From the earlier studies there was known to be a dearth of published material about the NAP project and that work for this book would need to uncover, as it has done, the primary source material. Inevitably, therefore, cross-referencing and corroborating the evidence would become important. Furthermore, there are no individuals alive today who were involved in *all* the developmental aspects of NOP and NAP and their revisions.[18] Therefore, the need to preserve oral histories and primary archive materials, before they get lost through the ravage of time, becomes paramount.

In order to assemble the meticulously established 'acts and facts' needed for an historical analysis, evidence was collected over a five-year period and it can be broadly grouped into three types:

- ORAL SOURCES
  interviews, phone calls, lectures, and verbal discussions;

- INFORMAL DOCUMENTS
  personal letters, memos and notes;

- FORMAL DOCUMENTS
  published books and articles, theses, newspapers and periodicals, newsletters and policy documents, and prepared minutes of meetings.

This evidence was triangulated so that statements made in one source could be checked in another. A good example can be found in Chapter 1 about the events that occurred during the initial 'pilot phase' stage for Nuffield A-level science at a physical scientists' meeting arranged by Mott in 1964. The carefully recorded minutes, widely distributed, hide the anger and frustration felt by Nyholm following a public attack by Rogers on the academic worth of chemistry as a subject. Ironically, the exchange occurred during a discussion about attempts to integrate physics and chemistry at A-level. And it can be argued that NAC and NAP, as separate A-level projects, originated at this meeting.

The first indication of a conflict came to light in an interview with John Spice and then corroborated with documentary evidence found in Spice's personal correspondence with Nyholm and, further, in Maddox and Keohane's co-ordinating correspondence. Finally, Spice published a few lines of Rogers' 'teasing' in an article dealing with physics in chemistry. Unfortunately, both Rogers and Nyholm died before they could be confronted with this issue personally and even then they might not have wanted to recollect the events after a span of nearly 30 years. Clearly, then, obtaining and using oral evidence is problematic, based as it is on imperfect recall, loss of data and, as Ogborn says, the danger of 'making up the story'.[19]

Some of the events recorded in Chapter 3 further illustrate the point. Paul Black and Jon Ogborn, the university-school concord appointed after Long's resignation to revitalize the ailing NAP project, provided a great deal of accurate oral evidence, but on one issue there seemed to be a difficulty in recall. Correspondence between Black and Officers at the Oxford and Cambridge Board about NAP examination procedures seemed to indicate an element of frustration by the Joint Organizers. But neither Black nor Ogborn could recollect the concern, and there was no reason to hide the facts. Instead, they recalled a time when they had to argue strongly for their case, and over a number of years they developed a harmonious working relationship with the Board. What appeared problematic in the documents proved to be no more than a minor irritation in the fullness of time. Such experiences raise the obvious questions about 'historical facts' - are they the 'recorded events of the time which catch the researcher's eye', 'the rounded recollection over time' or 'an artifact of the researcher's interpretation' ?

In writing and reading histories such as this, it should not be forgotten that the events themselves, the curriculum projects, evolve from the personal experience, character and determination of those involved. Walker's brief historical analysis of the Nuffield Secondary Science project reinforces this view: "Curriculum projects necessarily exist in delicate professional, social and even political tissue within which trust, persuasion and personal influence play a highly significant part. The projects exist in situations where consensus is delicately balanced and often needs to be tactfully sustained."[20] The last words in Peter Kelly's Ph.D. thesis, submitted in the same year as his Nuffield A-level Biology project was published, summarizes the intense personal nature of experiments in curriculum development:

"It ***all*** depends on people!"[21]

The ever-present humanity exposes both the historian and the 'historical actors' to the problems of bias and overall loss of perspective.[22] For example, it could be argued, in Chapter 2, that the events leading to Long's resignation were a highly successful attempt on the part of the universities and the NFSTP to get rid of an incompetent Organizer and then replace him with 'their own men'. The actors would be keen in these circumstances to play down their self-interest. However, careful interviews and document searches do not reveal this level of self-interest. No such evidence was forthcoming. Keohane's and Wenham's open exposure of their own unedited files clearly reveals that the source of this conflict lay in a combination of Long's poor communication skills, initially gross underfunding of the three Nuffield A-level physical sciences projects, and the universities' perception of an A-level physics curriculum.

Over a period of time, Black has noted the tendency of 'outside observers' to erase the differences between each of the Nuffield science projects.[23] Waring, too, has identified their individuality and believes that the differences essentially stem from the autonomy given to each project organizer: "It is not surprising, then, that the way each project developed, the kind of people who worked for it, the way they were chosen, and its whole philosophy reflect, to a quite remarkable degree, the personality of the organizer and that, over and above a commitment to a discipline-centred inquiry approach to school science, there is no such thing as 'the Nuffield approach', but as many Nuffield approaches as there are Nuffield projects."[24] The Nuffield approach for each project, and each organizer, however, relates to a complex set of constructions that extend into historical, biographical and humanistic areas, and combine to produce something called curriculum development. Shipman's case study of the process of curriculum development highlight the complexity as well as the inevitable gaps in historical knowledge that occur over time: "Everyone sees a different moving picture of an event in which all are involved. There are differences in interpretation and disagreement about what actually happened, but these are not necessarily right or wrong."[25]

The potential audience, and critics, of this work should be aware of the complexity of the events and the effort needed to construct a detailed curriculum history. The underlying principle we have used in selecting data from the broad range of evidence, and in weaving the parts together, is to present a fair chronology of the NAP developments, with the purpose of making, in Walker's words, "....the world more answerable to understanding, not merely to rehearse its complexities".[26] An attempt is also made to get inside the minds of the decision makers in the NFSTP, as well as those of the physics teachers involved in the development, dissemination, diffusion and revision of NAP. While there are those still alive today who took part in the Nuffield revolution and who were close to events recorded here, they were not always aware of activities in other areas and, of course, carry with them their own personal recollections and impressions of meetings and people. Hopefully memories will be jogged and criticisms will be put into print. Such debate is sorely needed in physics curriculum history. Our major concern is that this curriculum history is detailed and accurate enough to transform any such debate, pose fundamental questions and then, perhaps, to point to 'new agendas' for development.[27]

The need for detailed information from many sources and files becomes apparent when historical references in the literature are inaccurate, especially those dealing with the Nuffield A-level physical sciences. For example, Ingle and Jennings make the point: "Shortly after the completion of the O-level work [1966-67], four new Nuffield projects were started, to carry forward work to A-level."[28] Whereas, in fact, the A-level pilot study period began in 1963-64 and the first A-level to get started, NAB, did so in 1965. In addition, the brief reference to the Nuffield A-level projects in McCulloch, Jenkins and Layton's book *Technological Revolution? The Politics of School Science and Technology in England and Wales since 1945* includes confuted statements attributed to the advisers and organizers of the NFSTP. The issues raised deal with the stimulus to initiate the Nuffield A-level programme and the attitudes of Professors Mott and Nyholm, respectively the Chairmen of the Nuffield O-level Physics and Chemistry Consultative Committees, towards the development of an integrated A-level physical science course.[29] Chapter 1 contains sufficient detail to sort out these problems.

Jon Ogborn, a central player in NAP's curriculum history, mused: "Education is a process with a long time constant, in which the problems of today are the fruit of the plans of the past and are the seed of the plans and problems of the future."[30] He was reflecting, in 1978, on the influence that changes in schools, caused by innovations such as his own NAP project, have on the physics curricula in higher education. The radical changes made by Long, Black and Ogborn, and the other gifted physicists involved with NAP, have become both 'fruit' and 'seed': the 'fruit' was NAP in schools being used flexibly by teachers and pupils (some of whom move into higher education), and the 'seed' is the influence NAP may have on the plans for the future. Both need to be exposed by a curriculum history.

Close scrutiny of the NAP project reinforces Waring's opinion that the sincerity and commitment of the historical actors dwarf and transcend any vested interests.[31] The NAP project team primarily wanted to 'do a good job' with the physics content, the teaching methods and the examination. Criticisms related to 'vested interests' and NFSTP 'elitism' are addressed in the later Chapters . Many of the critics use the idiosyncratic and provocative comments made by Rogers to support their arguments, and ignore the later developments in Nuffield physics.

Here, then, is a detailed historical narrative and biography of one A-level physics project conceived with its own unique style and content by a specially chosen group of physicists, and with a pedagogy largely determined by particular trials schools. It was heavily influenced by both school and university physics teachers and could call upon experiences and practices from the earlier NOP project, when needed. It has been noted that the Nuffield O-level Projects were surprisingly practical and sophisticated given that there was so little curriculum experience to guide them. [32] NAP created even more sophisticated processes than its O-level forerunners, and it stood the test of time, running from its trials in 1970 to its last examination in June 2001. Nonetheless, this curriculum history is also an 'open' history - there remain unresolved questions and the debate about the physics curriculum continues through developments such as the *Advancing Physics* course, funded by the Institute of Physics and developed under the leadership of Jon Ogborn, and the Salters-Horners A level (AS and A2) Physics syllabus.

K.D. Fuller
D.D. Malvern,
Reading 2010

CHAPTER ONE
Trying to catch up a bit

Part 1: Challenge and Change - the beginning of the Nuffield Foundation's role in physics curriculum development, and the response of some institutions.

The one hundred and fifteenth meeting of the Nuffield Foundation Trustees, held on Friday 8th December 1961, was a conjunction in British science education. The Trustees had before them two strategic papers, prepared by Dr.Leslie Farrer-Brown, the Director of the Foundation. One paper dealt with educational research and experiment in general (Paper F.115/1 - see Appendix 1), while the other dealt with the teaching of science and mathematics (Paper F.115/2 - see Appendix 2) [1]. In discussion, Sir Alexander Todd, F.R.S., expressed the view that:

> ".... the Foundation could be of great help if it were prepared to co-ordinate and finance the present ineffective and dispersed efforts towards educational reform. This was certainly the case in so far as science teaching was concerned."[2]

Todd was also Chairman of the Advisory Council on Scientific Policy and held many posts in the science establishment. He had been the focus of chemistry teachers' attempts to improve the curriculum.[3]

In the event, the O-level physics project, initially called the Nuffield Foundation School Physics Enterprise, was to be the flagship for the attack on school science curriculum development for pupils aged 11-16. Physics enjoyed high status as a subject and a lot of work already carried out at the time had been in this area of the science curriculum. Acting urgently on advice given by physicists at the Royal Society and the Institute of Physics and Physical Society (IPPS), Mr. Donald McGill, an HMI on the staff of the Scottish Education Department, was appointed as Organiser of the physics enterprise at the Trustees' 117th meeting on Friday 16 February 1962.[4]

There is a complex interaction between the various institutional levels of science education and the active, even zealous, involvement of school teachers and research scientist members[5]. The influential fellowship of the Royal Society in conjunction with the Institute of Physics have, over the past 60 years, generated considerable interest in physics education. In particular, they helped mould the ideas for Farrer-Brown's initiative to set up the NFSTP and, in the case of the O-level physics project, were instrumental in the appointment of the key personnel.

The present-day Institute of Physics has its origins in the amalgamation of the Physical Society, founded in 1874, and the original Institute of Physics formed in 1918. The combined body was called The Institute of Physics and the Physical Society (IPPS) which was in turn granted a royal charter with the title Institute of Physics in 1970. From time to time, groups of like-minded physicists would form working parties and in 1945 a separate Education Committee within the IPPS was set up to deal with graduateship examinations and to give advice on policy and syllabuses.[6] This concern has been maintained until the present day.

The Royal Society, on the other hand, had only shown an intermittent interest in science education.[7] However, the British National Committee for Physics had been established by the Royal Society since the early 1930's and the IPPS was represented on this body. Among the seven items for discussion at their meeting on the 26 January 1961 was the teaching of physics, and, in particular, which group should take responsibility for the subject within Great Britain. Debate focused on a report of an international Conference on Physics Education held at UNESCO House, Paris, from 28 July to 4 August 1960. Norman Clarke, from the IPPS, was conference secretary and together with Professor Sanborn Brown from the USA prepared a full report of the proceedings.[8] The university physicists present at the Royal Society advised that such an education group should have a wide representation from universities, schools and examining bodies:

> "It was agreed that a Committee should be set up, either by the Royal Society or the Institute of Physics and the Physical Society. This Committee should be asked to concern itself with, *inter alia*, the reviewing of text books, teaching methods generally and the organisation of conferences dealing with the teaching of specific aspects of physics".[9]

Professors C.C.Butler and D.A.Wright acted as intermediaries with help from Dr.D.Martin, Assistant Secretary to the Royal Society, and Norman Clarke, the Deputy Secretary at the IPPS. Membership of the joint committee was established by the autumn of 1961. It was called the

National Committee on Physics Education [10] with Professor Sir Nevill Mott as Chairman and Norman Clarke as Secretary. Half of this committee would eventually take up important positions in the NFSTP and Clifford Butler was to become Director of the Nuffield Foundation in 1970 and very involved in A-level curriculum policy through the Butler-Briault proposals, the N and F debate (see Chapter 4).

To begin with, they discussed in broad terms the sorts of improvements needed for physics teaching: the provision of teachers' guides to help presentation, the development of new or improved equipment, courses for teachers and any other means to revitalize school physics teaching.[11] It was also suggested that Clarke get in touch with one of the charitable foundations to seek their assistance with the very substantial costs: "It so happens that, before I was able to do this, the Director of the Nuffield Foundation approached me".[12]

For some time the Nuffield Foundation had been interested in educational renewal[13] and during the first half of 1961 the Director, Leslie Farrer-Brown, and his Assistant Director, Tony Becher, had contacted a wide variety of people involved in education. Farrer-Brown went as far as asking John Lewis if he would be prepared to lead a Nuffield sponsored physics project. Although Lewis declined, because he was about to become a housemaster at Malvern College, he and another member from the National Committee on Physics Education, Norman Clarke, met Farrer-Brown on the 30 October 1961 for a discussion "...to try to define more clearly the nature of the current wave of interest in revising the basis of science teaching..."[14]

The numerous and relatively independent approaches being made to the Foundation to advance the content and method of science teaching had prompted its officers to search for realistic proposals with proper and coordinated direction. The proposals for physics seemed the most advanced and 'ripe for further positive action':

"As a first step we would like to have a talk with Mott, Chairman of the new National Committee on Physics Education, and Clarke, who is also Secretary of this Committee.... We hinted that the Foundation could be closely interested and prepared to come in with large scale support."[15]

It was agreed that the main need in physics was support for carefully selected individuals to implement the ideas discussed at the National Committee on Physics Education meetings. Clarke and Mott had several discussions with Farrer-Brown and reached broad agreement to set up a Nuffield sponsored project, under the control of a director and small consultative committee appointed by the Foundation and including Mott, Lewis and Clarke.

> "We suggested to the Foundation that Mr. D.McGill, of the Scottish Education Department, should be invited to be director and this has been done."[16]

Having helped establish the Nuffield Physics O-level project the National Committee on Physics Education decided immediately to investigate sixth form physics: to approach the universities to find their views on suitable preparation for students entering for physics as a principal or subsidiary subject and the Examining Boards to discuss syllabuses for A-level physics.[17] Within 18 months, Professor Mott would formally approach the Nuffield Trustees, urging them to consider helping to regenerate A-level physical sciences.[18]

Six months after the initiative by the physicists on the British National Committee for Physics, the Royal Institute of Chemistry (RIC) approached the Royal Society to help set up a kindred chemical education committee.[19] Similarly, a biology committee was established later in 1962.[20] In time, the Nuffield Foundation would support the establishment of professional journals in physics education, chemistry education and biology education, thereby helping the professional institutions to explore ways to improve the interaction of school and university teaching.[21]

Other detailed historical studies[22] contain evidence of the influence on the work of the physics enterprise and, in turn, the NFSTP of the syllabuses in school science developed by the Science Masters' Association (SMA) and the Association of Women Science Teachers (AWST). But Layton records that at the time McGill accepted the post, some senior members of the SMA expressed concern at the complete lack of consultation over the appointment. He documents an abrasive exchange of letters between Dr.Henry Boulind, Chairman of the SMA's Science and Education Sub-Committee, and Tony Becher, an Assistant Director at the Foundation.[23] The initiatives by the National Committee on Physics Education helped to generate a feeling of 'take-over', which was more apparent in physics than in chemistry and biology.[24] Before the advent of the NFSTP, much work had been done in the 1950's by innovative science teachers in schools, colleges of education and H.M.Inspectorate under the auspices of the SMA and AWST.

The 'winds of change' in the late 1950's were funnelled through the strong personalities on the General Committee and the various sub-committees of the SMA. In physics, John Lewis[25] played a prominent and active role within the many threads that ultimately joined together to form the NFSTP. Many of these energetic and innovative science teachers had been stimulated by the Industrial Fund for the Advancement of Scientific Education, set up in November 1955: "By 1963, when the Fund was wound up, a sum of almost £25 million had been allocated for the building and equipping of physical science laboratories in over 200 independent and direct grant secondary schools."[26] Eraut concludes that industry was hoping to attract the best students into the physical sciences.[27] Moreover, these schools were in an advantageous position to recruit good science teachers from the 'limited stock available'.[28]

From these well equipped and fully staffed laboratories came a flood of ideas to introduce 'modern physics' into schools. For example, Boulind's article *Atomic Energy and Education* summarizes some of the ideas into a possible teaching syllabus.[29] Boulind's thoughts were honed at a UNESCO conference where the "...syllabus discussed resembles an "O" level syllabus in England but includes, in addition, some study of the methods of science, of modern scientific concepts, of the history of science, and of social and technical applications".[30] Furthermore, Lewis' laboratories at Malvern College received extra industrial funds to support the development of an experimental base and the equipment needed to teach atomic and nuclear physics.[31] Eventually, Malvern College would become the epicentre for the massive development of laboratory equipment needed to implement the Nuffield O- and A-level physical sciences.

Reacting to reports on the paucity of physics teachers and good laboratory provision, plus Boulind's damning international perspective on the physics syllabuses of the time, the SMA's General Committee formed a Science and Education Sub-Committee to establish policy and then to begin to construct detailed syllabuses.[32] In due course, E.H.Coulson , a chemist on this Sub-Committee, would become an important team member for the Nuffield O-level Chemistry (NOC) project and, in turn, the Organiser of the A-level project (NAC). A biologist on the Sub-Committee, W.H.Dowdeswell, would be appointed as Organiser of the Nuffield O-level Biology project, and Joint Organiser of the A-level project (NAB). None of the physicists, H.F.Boulind, H.F.Broad, E.W.Tapper and H.Tunley, became Organisers for the Nuffield Physics and Physical Science projects, although Boulind and Tapper were to make significant contributions to NOP.

As it turned out, the biology panel were the first to complete their syllabuses in December 1958, but the result was neither sufficiently radical nor imaginative.[33] In contrast, the chemistry panel completely restructured the teaching of chemical theory and their efficient and well-organised approach continued unbroken into the NOC and NAC projects.[34]

There was general consensus within the Science and Education Sub-Committee that physics teaching and physics syllabuses required most revision. The physics panel, however, did not hold its first weekend meeting until the end of 1958.[35] A draft syllabus was completed within 12 months and included 'much which has been discovered in the last sixty years', namely a substantial section 8, plus detailed notes, dealing with Atomic and Nuclear Physics. The theme throughout the O-level section was 'physics for all', not 'physics for the future specialist'. The physics syllabus was also widely accepted and received support from the IPPS.[36] Many members of the physics panel were also involved in the Institute's activities, particularly John Lewis and Lewis Elton.

In the late 1950's, Elton had carried out research in nuclear physics at the Massachusetts Institute of Technology (MIT) under Professor J.R.Zacharias, the inspiration behind the Physical Science Study Committee (PSSC).[37] Boulind in 1959 and Lewis in 1960 had spent summers in various parts of the United States, appraising the usefulness of PSSC research for British school physics.[38] The increasing emphasis on 'modern physics' in the teaching of both physics and chemistry prompted the physics panel to form a Sub-Committee on the Teaching of Modern Physical Science,[39] with John Lewis as convenor. This committee was charged to devise experiments and suggest suitable courses.[40] It was from Lewis' committee that many of the personnel required to implement the Nuffield physics projects were drawn. In particular, Lewis and E.J. Wenham, the Secretary, became the two Associate Organisers for the O-level project, and V.J.Long, HMI, became the first A-level Organiser. Therefore, it is important to chart the activities of this enlightened committee and explore the personalities of its membership.

By the end of 1960, the SMA subject panels were in a position to publish draft proposals for the chemistry and physics syllabuses. Many radical ideas had attracted the interest of the Universities and Examining Boards, as well as the HMI. So, in the period 20-22 December 1960, the Secondary School Examinations Council (SSEC)[41] convened a conference at Studley College, Warwickshire, to discuss the syllabuses.

Approval was given by the SSEC for most of the chemistry syllabus to be used by any examining body.[42]

The situation in physics required more discussion. The Staff Inspector for Science, Dr.Tricker, launched a powerful attack on the proposals put forward by Lewis' committee, stressing that the teaching of modern atomic theory should be based on convincing experimental evidence at GCE O-level, otherwise it would " ... would degenerate into the transmission of dogma."[43] Tricker himself began to explore how such experiments could be devised and he initiated research with an apparatus manufacturing company which eventually led to the Teltron hot-filament vacuum tubes used in NOP and school physics in general.

Meanwhile, his argument[44] persuaded HMI among others to suggest the Studley Experiment, in which a group of schools should be invited to undertake an investigation to trial new teaching and examining schemes.[45] Three Examining Boards (University of Cambridge Local Examinations Syndicate, Northern Universities Joint Board, Oxford and Cambridge Joint Board) agreed to assist with ten schools taking special examinations with each Board.[46] In addition, teachers were offered short courses at Malvern College to familiarise themselves with the new apparatus and the 'modern physics' parts of the syllabus. Groups of HMI and experienced teachers held one-day courses in each school, meeting science staff and pupils.

Eventually, a special O-level physics paper based on the Studley Experimental Course was set in July 1963, about the time that the NFSTP was beginning its own negotiations with the Examining Boards. The results suggested that "...significantly more schools had been penalised by taking the experimental papers than had been favoured."[47] The lesson of this embarrassing outcome was learned by Nuffield. When it came to examining the Nuffield physics courses, the NFSTP was to propose "...that the setting and marking of the experimental papers[Nuffield] should be a joint enterprise between the Nuffield examining teams and the joint working party set up by the collaborating Boards..."[48] The same boards were involved, with the Oxford and Cambridge Board accepting the responsibility to organise the special project examinations in Nuffield O-level Physics (and later A-level as well), and the outcome of the joint undertaking was happier as will be seen in Chapters 3 and 5.

The Science Panel of the SSEC, which included Tricker and Long amongst its membership, and through whose hands the Examining Boards' syllabuses must pass for approval, had opposed the inclusion of 'modern physics' topics unless they could be dealt with scientifically by being based on experimental evidence at the O-level stage.[49]

Aware of these requirements, and of the powerful lobby by Tricker that physics pupils should have experience of doing their own investigational practical work in topics like radioactivity,[50] Dr. (later Professor) Elton approached the Nuffield Foundation for a grant of £300 to add a five-day residential meeting at the Battersea College of Technology to the series of meetings being held at Malvern College.[51] Elton, as head of the Department of Physics, wanted to demonstrate:

1. That it was possible to teach modern physics at both O- and A-level in a fit manner and free from dogmatic statements by the teacher.
2. That such an approach was practicable from the point of view of apparatus and finance.[52]

Eventually, thirty-three teachers from schools, colleges and Departments of Education, together with HMI observers, met in Easter week, 4-8 April 1961, to clarify their ideas.

The results of their labours were published[53] and in his summing-up Elton reflected the view that the SMA should sponsor an authoritative text book on modern physics, approached through electrostatics and radioactivity:

> "It was clear that the American way of providing a large sum of money so that really able men could devote themselves full-time to textbook writing for one or two years had found supporters. Nothing on the financial scale of P.S.S.C. was contemplated, and it was felt that £100,000 would go a long way towards meeting the costs of such a project."[54]

Within twelve months, the hard-working members on the SMA's committee had written an interim report on The Teaching of Modern Physics.[55] The report was published by the SMA through a small grant from the NFSTP. McGill felt that a joint Nuffield and SMA publication would help allay the resentment felt by the Association's feeling of 'take over'. He also emphasised that Lewis' draft was not a finished product and that it would possibly "...look quite different at the end of three years, when it has been extensively tried out and more closely integrated with the rest of the physics course."[56] In the event, the Nuffield Foundation met the full production costs of the report and paid an honorarium to the principal authors in respect of copyright: "We agree that the S.M.A. would pay the Foundation a trade price of 5/- [5 shillings] per copy for the entire edition of

1,500 copies, though it would sell copies at a published price of 7/6d to non-members."[57] The NFSTP were able to use the report as a test-bed for their own publication plans.

These meetings had helped to crystallise the ideas of the SMA's Modern Physical Science Committee. The part-time nature of the SMA's science committees implied that further detailed development work and discussion of policy must await the next available stretch of time during the summer school holidays. So the SMA's Science and Education Committee decided to hold a meeting for all its working parties at Barrow Court, near Bristol, from 28 August to 2 September 1961. [58]

Meanwhile, Farrer-Brown, at the Nuffield Foundation, had been working steadily throughout the first half of 1961, involving himself and his Assistant Directors, Dr. McAnuff and Mr. R.A.Becher, in the 'educational state of the nation', particularly those problems perceived in physics: "Awareness of the grave national handicaps which this state of affairs produced had by now percolated through the educational authorities and the professional associations involved. The Royal Society, the Institute of Physics and the Physical Society were all concerned at the position, and both formal and informal pressures from these and other bodies finally induced the Foundation to act."[59]

On 26 July 1961 Farrer-Brown arranged a private dinner party at Nuffield Lodge, to promote informal discussion about science teaching in schools and to allow the Nuffield Trustees to meet representatives of the disparate interests.[60] The Minister of Science, Lord Hailsham, and the Minister of Education, Sir David Eccles represented the Government interest.[61] Clarke indicates the importance of this event, where "...a Ministry of Education note circulated in advance of the dinner suggested that there were now three main problems to be considered. These were (1) the scope of science teaching for non-specialists or those not taking science to an advanced level; (2) the curriculum for the future scientist; and (3) what should be done to ensure that the science specialist is also a generally educated man (or woman)."[62] This meeting served as a catalyst "...both to the Foundation's own thoughts and to the plans of others."[63]

In the next six months Farrer-Brown consulted a wide group of institutions and individuals involved in science about his ideas for experiments in science curriculum development. In particular, the Ministry of Education was involved at an early stage but the Foundation was adamant that they, themselves, would be in control of the experiments:

"It is by no means suggested that action should be deferred until the Ministry gives its blessing to the scheme: on the other hand, official co-operation on its part may be of some practical value at a later stage (i.e. in connection with the secondment of selected teachers) and, ultimately, in negotiations with examining bodies."[64] Moreover, the Ministry and HMI representatives were initially very critical of Farrer-Brown's proposals, especially his idea to start the reforms at O-level. Many of the Government representatives argued strongly that the work should begin at A-level.[65]

The Ministry's views were honed at a Science Panel meeting held on 4 January 1962, chaired by Staff Inspector Tricker and attended by the Permanent Secretary, Dame Mary Smieton, and a Deputy Secretary, Mr. Fletcher.[66] Dame Mary had attended the Nuffield dinner on 26 July 1961 and had held further discussions with Farrer-Brown on 11 December. She reported that the Trustees were proposing to assist science teaching in Britain: "Although they were going on with this irrespective of what the Ministry might say, they would like to have the support of the Ministry and would have regard to the comments they made."[67]

Two copies of a 'confidential document', Farrer-Brown's paper F115/2, were available at the meeting: one copy was held by the Permanent Secretary and the other by Dr.Tricker, who summarized the contents to Panel members. As a result, 'discussion was rather discursive' but a number of important criticisms emerged:

1.Dr.Tricker made the point that O-Level was not the place in which to start; it was necessary to start reform at A-Level and work downwards.
2.Doubt was raised about Farrer-Brown's assumptions(B4) that, as science should be a core subject 'for every child', the greatest need was for a satisfactory syllabus at O-Level; only a minority of children proceed to this stage, not the majority, as stated in the paper.
3.The Panel considered it unwise for the Foundation to tie themselves too closely to the SMA syllabuses.[68]

In conclusion, it was hoped that the Ministry would "...exert an influence on the Foundation by seeking to broaden its outlook. The Permanent Secretary hoped that it would be possible to get an assessor from the Ministry on any body that the Foundation set up to deal with the problem."[69]

As it turned out, Farrer-Brown resisted any direct Ministry assessment of the project teams. Key personnel in the O-level physics project, Professor Eric Rogers and Ted Wenham, both felt remarkably free from outside pressures, especially from HMI. Ted Wenham, in particular, believed that the astute Farrer-Brown foresaw the possibility of 'awkward situations' and actively maintained total independence for the Foundation's Fellows and staff.[70] Yet there is ample evidence of HMI personnel expanding the Foundation's horizons, but in Woolnough's opinion they have not received the public recognition they deserve.[71]

Both the Nuffield Foundation and the Ministry of Education were well prepared, when their officers met at 3p.m. on Thursday 25 January 1962. Four Ministry Officials, T.R.Weaver, L.R.Fletcher, D.H.Morrell and M.Kogan, plus three HMI, V.J.Long, P.Wilson and R.W.Morris, met Farrer-Brown and Becher from the Foundation. The influential Tricker, Staff Inspector for Science for 15 years, had just been succeeded by Dick Long.[72] Toby Weaver acted as the Chairman. He asked Farrer-Brown to expound on his 'confidential memorandum' and the Foundation's plans for the future: "They placed physics first, chemistry second and biology next. Work on mathematics might proceed simultaneously with work on the natural sciences...Development of primary science teaching would come last."[73] No mention was made of the A-Level curriculum, nor Newsom science (science for the average to below average 11-16 pupils). Weaver then detailed the Ministry's criticisms as outlined above, particularly emphasising that O-Level curriculum development would only influence a 'small minority' of the ablest children, and that perhaps A-level would be a better place to begin. Farrer-Brown replied that he wanted to avoid the specialist teaching at A-level and that to make a start in this field the Foundation would have to concentrate on a 'relatively limited sector'. But, at a later stage, it might be hoped to tackle curriculum directed towards the general education of the majority and some form of A-level renewal.

Discussion then moved away from the detailed Nuffield plans towards mutual help and cooperation. The Ministry was setting up a development group on school equipment, later to be known as CLEAPSE, a Consortium of LEAs for the Provision of Science Equipment, and they would pay particular attention to the needs arising from the introduction of modern physics in the curriculum. It was agreed to keep in continuous contact with the commissioning of the apparatus. Finally, Farrer-Brown agreed to contact the Ministry through Derek Morrell[74] and to keep them informed of further developments. It seems as though the Ministry had some success in broadening Farrer-Brown's outlook and indicating the need for 'additional stimulus' by the Foundation, but was unable to deflect him in his assumption to start the reforms with O-level physics.

Why, then, did Farrer-Brown believe that O-level physics was the best place to start the Nuffield Foundation's reforms, and why did he reject the Ministry's advice to start at A-level? In his own words, the intention was clear:

> "We must admit to having been influenced by a sense of urgency - as a country we are trying to catch up a bit."[75]

Waring's interviews with Farrer-Brown reveal that the catching up process was based on two assumptions:

1. to establish social experimental methods with real children and good teachers as a means to advance the science curriculum;
2. to give the intelligent child, who was not going on to be a science specialist, an awareness of, and familiarity with, the habits and thoughts of the scientist.[76]

The first stemmed from Farrer-Brown's previous experiences in a debate about primary French teaching, and in his discussions with John Lewis about physics teaching in other countries.[77] While Elton strongly supported an experimental approach to curriculum renewal, he has questioned Farrer-Brown's assumptions about teachers. Some teachers could resent an approach that dictated content and teaching methods, whilst average teachers might find it difficult to take up the ideas with little or no in-service training.[78] Clearly, tradition and a dominance of grammar school thinking lay behind both assumptions. However, there were many good and brilliant physics teachers in O-level grammar and independent school classes at this time, many familiar with the PSSC materials and some involved in Mott's National Committee on Physics Education.[79]

Alternatively, in 1960, the Ministry and some HMI had argued for general science for all pupils 11-15 but at the same time admitted that there were doubts as to whether a worthwhile course could be developed by such an experimental means.[80] In addition, the Ministry was also concerned that Farrer-Brown's proposals would not reach a broad ability range of secondary school pupils. In consequence, they proposed that the Nuffield reforms should begin at A-level and then work downwards. It is unclear whether they meant A-level science as a single subject or as separate A-level sciences. These arguments did not satisfy Farrer-Brown's second assumption, namely to provide science for the intelligent non-scientist and so help reduce the 'two cultures' gap.[81]. Hence it was Farrer-Brown's value judgement, to start with O-level physics where curriculum ideas had already been tested in the Studley experiments, and an advisory committee had been established by the Royal Society and the IPPS.

Farrer-Brown's 'catching-up' phrase arose in an early debate about the nature of NOP and McGill's use of the phrase 'physics for all', a term derived from Boulind's influence on the SMA's physics syllabus.[82] Both McGill and Halliwell were anxious to try to develop courses for the top end of the secondary modern schools, as well as for grammar schools: "I [McGill] would like in public discussions to resist (the theory) that we are trying to cover [the top] 20% of the population - the field is wider. It would be rather unfortunate if the wrong label was attached to us in such a way."[83] But Mott and, later, Rogers were anxious that NOP would appeal to the 'most intelligent boys'. The notion that NOP, and later NAP, are elitist courses that stem from a *'Fortress Nuffield'* mentality has its origins in these very early debates, although quite clearly the project team put forward arguments against exclusivity.

Of course, Farrer-Brown's assumptions, and their translation into the work of the NFSTP, have been criticised in hindsight. For example, Michael Young finds in these decisions perverse motivations of social control, in order to impose a class structure on society: on the one hand to create a large scientifically illiterate workforce and, on the other, to create a physics elite.[84] Using a different perspective, McCulloch argues that NOP, following on as it did from the SMA developments and the Industrial Fund, were deliberately created with an 'elitist vision'. The basis of the elitism is grounded in the 1950s grammar and independent school education, designed to equip the UK's future leaders with scientific and technological knowledge and skills.[85]

But within the individual NFSTP developments both Waring (NOC) and Woolnough (NOP) have found a high degree of altruism and pragmatism among the project teams. Their professionalism and sincerity tended to dwarf any vested interests and even though they created high status, intellectual science, they "...would have been very surprised to be accused of propagating a type of science which was politically and socially divisive."[86] In a similar vein, the NAP team were also mainly concerned to 'get the physics course right', although they were more conscious, as a second phase development, of the need for political awareness and partnership .

Naturally, in the early discussions about the formation of NFSTP, many of these political and social issues were raised with Farrer-Brown and some appear in his policy papers . But during the latter stages of 1961, as Farrer-Brown was preparing his carefully researched papers in time for the decisive 115th Trustees' meeting, on 8 December, the SMA were feeling the erosion of their power base in the O-level science curriculum. The shift in power from the SMA to the Nuffield Foundation took place between the autumn of 1961 and the spring of 1962.[87] The first signs became apparent at the Barrow Court conference organised by the SMA during 28 August to 2 September 1961. The purpose of the conference was made clear in Coulson's opening remarks, that the SMA were unable to finance any future curriculum development based on their syllabuses. As over half the people attending were physicists, discussion soon turned to the Royal Society and the IPPS's initiative to help finance some development in physics. Elton reinforced the conclusions from his earlier conference and felt that the SMA should take the lead and obtain help from the Ministry.[88]

The remaining days at Barrow Court were less evangelistic and were devoted mainly to discussions about the SMA/AWST syllabuses. However, plans were made for Boulind to approach Sir Alexander Todd and elicit Ministry help through the National Advisory Council on Scientific Policy. Two weeks later Todd advised the SMA that the Government did not want to intervene directly in curriculum matters and he suggested that the SMA write to the Nuffield Foundation.[89] The SMA/AWST request arrived in time for the Trustees' December meeting, only to be circumvented by the Nuffield Foundation's own plans for curriculum renewal.

At the meeting the Trustees, and Sir Alexander Todd in particular, assented to coordinate and finance educational reform in science. They agreed that in this initiative to research and experiment "...the Foundation should not function solely as a grant-giving body, but should participate actively in the planning and operation of the exercise as a whole."[90] Although the Trustees first set aside funds of not less than £250,000 for the purpose, after detailed consideration, an initial grant of £374,745 was allocated "...to investigate the curriculum and to produce teaching materials for a five-year course leading to O-level in each of the three sciences."[91]

In February 1962, the Trustees appointed Donald McGill to implement the physics project. The scale of the investment, plus the appointment of key physics personnel recommended by The National

Committee on Physics Education, furthered the 'take over' of the earlier SMA/AWST work in physics. For example, of the eleven members of the SMA/AWST physics panel only Lewis, Boulind, Wenham and Sister St Joan of Arc were invited to join the NOP development team and none of the physicist on the SMA Science and Education sub-committee became an organizer for any of the Nuffield projects. In particular, Elton was also excluded, despite his work in the 'modern physics' developments. However, his advice as a university physicist was sought later during a confrontation between SCUE physicists and the NAP project.

The take over was completed when McGill received advice from the National Committee on Physics Education to prepare a new and forward looking physics syllabus:

> “Mr. McGill expressed concern at the restrictions imposed on him in the letter he had received from the Nuffield Foundation, in which it intimated that he should proceed along the lines set out in the new S.M.A. syllabus. The committee [the National Committee on Physics Education] considered that this was meant as a guide and that Mr. McGill should feel free to progress from the S.M.A. syllabus, modifying it where necessary.”[92]

An Advisory Committee, later called the Consultative Committee, was set up to represent all possible interests and to assist the physics organiser. The original members were:

Chairman:	Professor Sir Nevill Mott, F.R.S., Cavendish Professor of Experimental Physics in the University of Cambridge.
Secretary:	Mr.Donald McGill, HMI, Scottish Education Department.
University Members:	Professor R.V.Jones, Professor of Natural Philosophy in the University of Aberdeen. Professor C.C.Butler, Professor of Nuclear Physics at the Imperial College of Science and Technology, London.
School Members:	Mr. John Lewis, Senior Science Master, Malvern College, and member of the SMA's Science and Education Committee.
Institute of Physics:	Mr. Norman Clarke, deputy Secretary, The Institute of Physics and the Physical Society.

Later the Committee was enlarged to represent a wider cross-section of interests in the curriculum renewal.[93] With the formation of the Nuffield O-level physics project, the Foundation was able to use its independent position to bring together the different interests and act as a focus for a national effort to reform the teaching of science and mathematics.

Part II: From Enterprise to Project - a brief record of developments in the Nuffield O-level Physics project.

On 4 April 1962 the NFSTP was officially launched in a House of Commons Statement made by the Minister of Education, Sir David Eccles, and a simultaneous press release spelled out the details and emphasised the co-operative nature of the enterprise.[94] It was at the inaugural NOP Consultative Committee meeting, held on 15 May 1962, however, that McGill was first able to explain his views on the 'physics topics':

> "If the establishment of working ideas rather than facts is made the primary objective of the course then the first step in building the syllabus should be to distinguish the main concepts aimed at in the course and build upon them a framework of essential ideas on which a teaching syllabus can be erected."[95]

McGill, of course, had substantial experience in developing physics syllabuses involving change in content, teaching method and active pupil participation. Since 1959, when he joined the SED, McGill had worked with groups of physics teachers to produce pilot trials materials which resulted in the new Alternative O-grade schemes being introduced in Scotland during 1962. [96]

This experience prompted McGill to suggest that the enterprise should initially proceed on three main fronts:

1. To prepare the basis of the course around clearly distinguished 'concepts', rather than 'subjects', where teaching methods should be taken into account as well as content.
2. To finalise a list of names of people able to help the project i.e. 'first lieutenants' distributed on a regional basis. Seconded teachers should carry out a good deal of the writing and experimenting.
3. To commission memoranda dealing with background physics and topics inside the accepted curriculum. Such memoranda would establish background information and enrich the writing of teachers' and students' guides.

Not surprisingly, the discussion at this first meeting was wide-ranging and reflected the considerable experience of Lewis and Clarke. Farrer-

Brown, however, was smitten by a sense of urgency, and hastened the Consultative Committee to decide on the seven, or eight, concept areas so that the 'right people' could be seconded quickly.

McGill, based at Nuffield Lodge, Regent's Park, London, synthesised a draft set of concept areas for a physics syllabus: Length, Mass, Time, Flow, Energetics, Fields, Oscillations and Waves, Quantum phenomena. But opinion at the second Consultative Committee meeting was divided and so a major conference was arranged for September.[97] Also during May McGill carried out an active correspondence with university physicists, and with the SMA, seeking out 'all too precious' physics teachers to be involved in NOP.

Eventually, the following regional organisation was proposed:

CONCEPT	REGION	TEAM LEADER
Fields	Birmingham	E. Wenham
Modern properties of matter	Bristol	Sister St.Joan
Classical properties of matter & mechanics	Scotland	W. Ritchie
Waves and oscillations	London	J. Goodier
Energetics	Manchester	R. Stone
Quantum phenomena	Malvern	J.L. Lewis
Examinations	Cambridge	H.F. Boulind
Reserve Team	Northumbria	R.D. Harrison
Reserve Team	Yorkshire	D. Layton

The third of McGill's opening strategies concentrated on involving senior university personnel in the physics enterprise, and spreading the word about the organisation and conceptual approach to the physics curriculum. McGill commissioned memoranda designed to provide the teams with valuable background material in physics and, hopefully, enrich the teaching materials. As well as providing publicity for the NOP, McGill's memoranda mandate stimulated the publication of creative ideas that would, in turn, be even more useful in the Nuffield A-level science projects.[98]

Throughout the summer of 1962 McGill worked very hard to bring all these threads together in time for the major physics conference held over a long weekend, Friday 28 to Sunday 30 September 1962, at the Hughes Hall in Cambridge. The overall aims of the conference were to discuss the selection of McGill's chosen concepts, to establish the chain of ideas underlining each concept, and to look for ways to link these ideas to the other O-level projects, notable NOC.

On Friday morning, McGill met all his team leaders together for the first time and explained that each group would receive £1,000 to develop their concept: "In terms of the average schoolmaster's expenditure it is a large sum of money; as an experimental basis very small." Secretarial help and the duplication of papers would all be carried out on a local basis. And McGill reminded his colleagues that the teams had been recruited on a regional basis because:

1. the physics enterprise is primarily a 'teaching experiment' and the aims will not be realized by just 'talk and laboratory work';
2. the teams have no statutory powers: they must educate local universities, examinations boards and schools;
3. the work is interesting and exciting and being involved is beneficial to local physics teachers.[99]

McGill urged his leaders to start by arranging a team meeting and then immediately delegate parts of the development work. It was important for widely scattered teams to exchange their ideas. To this end, during 1962-63, five Physics Enterprise Newsletters, full of information from the regional meetings and laboratory trials, were distributed to team members and personnel closely associated with the NFSTP.[100]

The afternoon session began with a welcoming address by Leslie Farrer-Brown, followed by key-note speeches from Sir Nevill Mott on *School Physics for Everyone* and from Donald McGill explaining the role of The Nuffield Physics Enterprise. Wide-ranging discussions signalled a divergence of opinion in the phrase 'physics for all'. Halliwell, the recently appointed NOC Organizer, suggested that the term should not be used at all if the NFSTP was aiming at the needs of grammar schools. Mott was emphatic: "We are devising a course which will be suitable for the most intelligent boys." In contrast, however, McGill publicly stressed that he was trying to cover a wider field than just the top 20% of the population. Boulind supported McGill and felt that the enterprise might be suitable for the top streams in modern schools.

Finally, at the end of a long first day, the enlarged physics Consultative Committee held a meeting to update information on the physics memoranda, the development of visual aids and apparatus, and of long-term importance to the O-level project, the full-time secondment of Dr. Boulind to establish an examinations group in Cambridge.

The second day of the Cambridge Conference, Saturday 29 September 1962, was notable for the lucid analysis of the 'concept areas'. Each team leader introduced their ideas and Mott chaired the lively discussions that followed:

"The constitution and properties of matter"	Sister St.Joan
"Quantum phenomena"	J.L.Lewis
"Mechanics and classical properties of matter"	W.R.Ritchie
"Energy"	R.Stone
"Fields"	E.J.Wenham
"Oscillations and Waves"	Dr.J.Goodier.

Fortunately, the proceedings were recorded by a verbatim reporting service, the Palantype Organisation Limited. McGill was most anxious that he had got the right concepts to form an appropriate base for the course, and he expressed the need for a good deal of discussion from the school teachers and university scientists present. He affirmed his commitment to a double revolution in both content and method. For instance, the enterprise needed a balanced statement of physics designed to meet the needs of future non-science specialist citizens, together with appropriate teaching methods that relate to the intellectual development of the child:

> "...if we change our ideas about the nature of science teaching and use some of the new methods, we do not know what can be done until we try it. We have got to try any worthwhile possibility. We have got to cost it in terms of teaching time based on experience."[101]

The extent of the Nuffield physics revolution was clearly illustrated in Ritchie's presentation showing that 'modern physics teaching' could be applied to the familiar mechanics and classical physics as well as to the new quantum ideas. His experiences in Scotland using ticker-tape and flash-photo techniques provided evidence that a cyclic 'operational approach' to motion resulted in pupil involvement and, eventually, "...a much more clearly grasped concept."[102] His only concern was that the examination system would have to change so that it did not inhibit teachers from allowing time for experiment. The perceptive Henry Boulind posed a related question:

"Are we moving towards a kind of examination which does not completely or even moderately cover the entire syllabus?".[103]

In a little over twelve months' time Boulind would become involved in intricate negotiations with the Oxford and Cambridge Schools Examination Board on the format and style of the Nuffield O-level physics examination.

Ted Wenham's exploration of 'Fields' raised two important issues. The first involved which type of units would be adopted by the teams - the M.K.S.A. system or the c.g.s. system. Wenham felt that the project should look forward to A-level physics and, as a matter of high priority, decide to opt for the M.K.S.A. approach. His second concern focused on the level of maturity at which children can grasp the full significance of matters like fields and energy: "I am convinced that one of the first things that we must do is to look into this question of the level of maturity which is necessary to grasp certain concepts." Wenham called for assistance and discussion of related research being carried out at the Leeds Institute and based on Piaget's theories and experiments.[104] Woolnough maintains that the physics team as a whole were not influenced by Piagetian thinking.[105] Certainly, McGill regarded Piaget's ideas as important in the 'operational approach' to teaching method; he specifically made a reference to Piaget's psychology in his opening speech to the Cambridge Conference. Moreover, McGill felt that the need to experiment with teaching methods in order to find the most suitable level for understanding was the prime reason for setting up the regional teams in the first place.[106]

The clearly relevant and important question on copyright and confidentiality was raised by Farrer-Brown in the last session of the conference: "One wants to retain freedom for you to change your minds before you reach the stage when you want to put out the whole thing. Experience in like enterprises has convinced us that the only way to get that freedom and to avoid embarrassment is to be rather brief and then, when you are ready, put the entire thing out as a whole."[107] Despite the inherent difficulties in maintaining high levels of confidentiality the physics team was able to minimise 'leaks'. Many vested interests were critical of the secrecy but Farrer-Brown's policy was vindicated at publication:

> "Later came a whisper, then a rumble and now a roar - NUFFIELD!...Many teachers have been involved with the work of the Nuffield Science Teaching Project over the past few years, but many more, including your reviewer [not named here], have not. Those not involved have merely hovered on the fringe, wondering what has been going on behind the curtain of secrecy. One understands why this curtain has been necessary."[108]

For the O level project, then, keeping things close was to prove successful, but the rousing publication of NOP in 1966 would immediately stimulate considerable debate about the physics curriculum in general, and the methods and ideas behind the NOP project in particular. The physics curriculum would be projected into the public domain, and as the broadening of such exchanges coincided with the formation of NAP, the O-level policy of keeping quiet become no longer tenable for the A level project. Unfortunately, the vestiges of this secrecy policy remained in Long's first NAP project and helped heighten a sense of communication breakdown between the universities and the schools. Dick Long's active involvement in the NOP project would inevitably lead him to adopt a similar management style and curriculum platform in the first NAP project:

- secrecy and poor external communications;
- organizing the project at a distance from the NFSTP;
- a devolved development team;
- lack of a traditional syllabus;
- a course based on concepts and themes.

All of these 'NOP factors' were, in time, to act against the initial acceptance of the NAP course, especially by university physicists .

By the end of 1962, however, McGill had developed a working liaison with the newly-formed chemistry Headquarters team, also based at Nuffield Lodge. Immediately after the Cambridge Conference, the two Consultative Committee Chairmen, Professors Mott and Nyholm, had met to discuss the common ground between physics and chemistry. In particular, Nyholm was anxious that both projects used the same words for the same concepts. He also felt that there were many subjects that belonged to physical science rather than just the separate disciplines. Mott was pleased with the useful dialogue and felt that he could work effectively with Nyholm.[109]

In time they would expand these ideas and use the integration of the physical sciences as a central argument in their plans to convince the Nuffield Trustees to carry out A-level curriculum renewal. Although instrumental in proposing there be but one Nuffield A-level physical science project, Nyholm was later to intervene and cause the development which created three separate projects in physics(NAP), chemistry(NAC) and physical science(NAPS).

Professor Sir Ronald Nyholm, FRS, assumed a central role in the smooth evolution of the Nuffield O-level and A-level chemistry projects from their traceable origins in the SMA chemistry syllabuses. He provided the social cement, contacts and intellect to help create an efficient and effective Nuffield chemistry section.[110]

Challenged by the chemists' rapid progress Donald McGill spent the last months of 1962 preparing his syllabus and a first draft set of interpretive notes. McGill, however, was now planning to use his trump card. He invited Professor Eric Rogers[111] to lunch at Nuffield Lodge. Rogers had been intimately involved in developing the PSSC project in the USA. In addition, he was interested in teaching physics as a liberal art to non-scientists at Princeton University. This stimulated Rogers to write his famous and unique book *Physics for the Inquiring Mind*, which was designed to support his innovative 'Block and Gap' physical science curriculum.[112]

After the meeting McGill invited Rogers to join the physics Consultative Committee and to act as a freelance advisor to the regional groups.[113] Rogers was on a year's sabbatical leave in his native England and readily accepted. During this time, McGill was taken ill with high blood pressure. Undeterred, McGill, and Rogers, attended the fifth and sixth Consultative Committee meetings held on 30 November 1962 and 31 January 1963 respectively. At this last meeting some disquiet was expressed by 'responsible university opinion' that "...our proposed syllabus moved too far towards modern physics and abandoned too much of what was valuable in the traditional approach."[114] Professor R.V. Jones, attending his first meeting, was critical of the 'black box' character of some of the first year experiments. McGill suggested that the best way to attest the project's ideas, and provide an exposition of the teaching methods, was to hold the next meeting at Imperial College, London, "...mounting an exhibition of Nuffield 'O'level physics equipment and teaching methods for the occasion."[115] Professor Butler argued that the exciting work in the O-level syllabus must impoverish A-level physics and McGill was asked to produce a paper "...showing what was proposed for 'A'level as a sequel to Nuffield 'O' level physics."[116]

Donald McGill was unable to formulate a policy decision on A-level physics. Tragically, he was admitted to the Lindo Wing at St.Mary's Hospital, Paddington, on 15 February 1963 with a recurrence of his earlier illness. He was ordered to have a month's rest and undertake medical treatment.[117] Donald McGill died on 22 March 1963, aged 52. In slightly less than a year McGill had "... started the project on its way and laid its foundation with such surety that even some of the traumas that were to follow could not disturb."[118] The Nuffield Trustees recorded their deep regret at such an untimely death and praised McGill's enthusiasm and devotion. They reacted with sympathy to his widow and agreed to make her 'ex gratia' payments for three years.[119] Ted Wenham's sensitivity sums up the loss: "...the Enterprise had lost a brilliant and capable leader; the members of his team had lost a friend."[120]

A 'YEAR' IN THE LIFE OF DONALD McGILL

April 1962	NFSTP Press release
	Formation of NOP Consultative Committee
May 1962	Donald McGill's release from the SED
	First and Second Consultative Committee meetings
	Meeting to arrange NOB
June 1962	Finalising Nuffield Fellowships for NOP
	Organizing the University Memoranda
	Selection of physics 'concept' areas
July 1962	Final composition of Consultative Committee
	Acceptance of teacher secondments
	Third Consultative Committee meeting
September 1962	Cambridge Conference
	Fourth Consultative Committee meeting
	Start of the NOC project
October 1962	First Team Leaders' meeting in London
	Meetings to link NOP and NOC
November 1962	Publication of three NOP Newsletters
	Visits to regional NOP groups
	Admitted to hospital with high blood pressure
December 1962	Fifth Consultative Committee meeting
January 1963	Start of NOB project
	Sixth Consultative Committee meeting
	Call for ideas on implications for A-level physics
February 1963	Third draft NOP syllabus
	List of NOP experiments & Imperial College exposition
	McGill in hospital for a month's rest
March 22 1963	Donald McGill dies, aged 52

Professor Eric M. Rogers was officially installed as the new Organiser for Nuffield O-level Physics (NOP) at the Trustees' meeting on 17 May 1963: "Professor Eric Rogers was to act as organizer with Mr. John Lewis as associate organiser....Professor Rogers would be mainly responsible for the final shaping of the syllabus and the writing of the teachers' guide. Mr. Lewis would be mainly responsible for apparatus developments and practical work."[121] In order to maintain the momentum in the physics project the Nuffield Directors, Farrer-Brown and Becher, had responded rapidly to Donald McGill's death. Farrer-Brown in his usual way spoke to every physics team leader to nominate a successor. The unanimous and independent choice was Eric Rogers.[122] At first, to circumvent any feelings of an ‘American PSSC take over’, Farrer-Brown sought John Lewis to act as a Joint Organizer. Rogers, however, would not accept dual leadership.[123] Rogers knew that he would have to act fast - Princeton University had generously granted a second year's leave, until 30 September 1964, to complete NOP's experimental development phase. In the period of limbo caused by McGill's illness, Rogers had acted as a close consultant to the NFSTP. He stood in for McGill at important equipment and film meetings.

If anything, Eric Rogers' renowned energy, knowledge and enthusiasm increased the tempo, and temperature, within the project: "His[Rogers] distinction as a creative physicist carried conviction, but his idiosyncrasies and single-mindedness were to produce a certain tension throughout the team during the development and re-writing period."[124] Lost time and a tight time-table set by circumstances forced Rogers to be single minded. In only five months, May to September 1963, first draft teachers' guides were written. "...full enough to enable teachers who were to take part in the preliminary trials in the academic year 1963-64 to teach the material in the way the team envisaged."[125] Rogers liked McGill's Mk. III syllabus and suggested a few changes:

> "My first impression is that the order is good but the sum total of topics seems to me to be too great particularly if justice is to be done to atomic matters at the end. In general, I would rather see the earlier years too full than the later years, so that if teaching lags behind there is still a chance of doing justice to the things at the end."[126]

In a ferment of activity, the regional groups began their experiments and fed back their comments on the syllabus. Team leaders began to synthesize teachers' guides for the various years and at the same time Rogers wrote a parallel version. Both scripts were combined, with difficulty, during the summer of 1963 and were ready for pilot school trials in the academic year 1963-64. [127] For example, Rogers explains his concern to Ted Wenham: "As I go through your Year II and write my longer version, I grow more and more delighted with your version. I liked it originally but now find extra delight in its compactness; and I writhe with anxious doubts about my longer form..."[128] In time, the sensitive, practical Wenham would become an important sounding board for Rogers' ideas and doubts. Not all the team leaders could forge such a good working relationship, however. Jack Goodier found he could not work with Roger's autocratic leadership and resigned from NOP. On the other hand, Rogers did not want to use the joulemeter being developed by Roger Stone and Geoffrey Foxcroft and he marginalised their work on 'energetics'. It was the productive working relationship, mutual respect and friendship between Wenham and Rogers which stabilized NOP and, crucially, continued into the project's revision during 1971-80.

Eric Rogers returned to Princeton University in the Autumn of 1964 and the new NOP organisation proposed by Mott and Maddox began to move the project inexorably towards publication. During the period 1965-67 Rogers would conduct an extensive correspondence with his Organizers and Team Leaders, especially with Ted Wenham who had the added responsibility of cementing together the now devolved NOP project. Just before his return to the USA Rogers helped lay a firm foundation for the NOP project in the trials schools, by securing the cooperation of the Examining Boards and arranging in-service training for teachers.

Tactful negotiations with the Secretaries of the Examining Boards were initiated by Tony Becher late in 1963.[129] On 12 February 1964 the Secretaries lunched at Nuffield Lodge with an informal exchange of views on examinations and the NFSTP:

> "I [Becher] do not think we can emphasize often enough to the Boards that our aim is to produce an entirely new kind of examination with an entirely new system of marking. This is a heaven-sent opportunity for us to get away from the present conventions, and I would be very sorry indeed if we did not grasp the nettle with unprecedented firmness."[130]

At this time the Examining Boards had a constitutional requirement for the Nuffield O-level projects to produce an examination syllabus. But from its inception the NFSTP had emphasised their commitment to a new teaching approach and to changes in subject content. Consequently the Nuffield O-level projects needed examinations to be set and marked with a different viewpoint, with questions that asked for thinking and well-understood knowledge and did not emphasise traditional definitions and rote memory.

It was at this stage that the Nuffield O-level Organizers became fully involved and they were firmly against giving the Boards a syllabus.[131] In particular, Eric Rogers persuaded Becher to resist proposing a traditional style syllabus. Rogers' radical intention for the NOP examination were first presented at an OECD conference on science education, held in 1964, and his paper was eventually published in the NOP Teachers' Guide.[132] Rogers also found an ally in Derek Morrell, who recommended that the NFSTP "....should not submit any syllabus of the normal pattern, i.e. a mere list of topics to be covered....and should produce for the Boards concerned and for the S.S.E.C. either complete or summarised versions of the teaching course (presumably complete physics teacher's guides, the chemistry handbook and the biology synopsis, together with a specimen teacher's or pupil's guide)."[133] By April 1964, Rogers had been informed by A.E.McKenzie, the Joint Secretary of the Oxford and Cambridge Schools Examination Board, that they had been appointed to administer the NOP examination. The NOP Awarders would be Dr.Henry Boulind and C.W.Kearsey from the Cambridge Local Examinations Syndicate. Eric Rogers was particularly relieved by these events:

> "To my great pleasure, the representatives of the Examining Boards and the S.S.E.C., under Dick Long's guidance, accepted the necessity of using all five years of the Teacher's Guide in lieu of a compact syllabus. I was most impressed by their intelligence in seeing so quickly that reduction to a syllabus would lead to a misconstruction of our essential aim."[134]

The trials schools could now be given firm assurances that their O-level results in science would not be jeopardised.

In order to promote an interest in the task of training teachers to master and accept the NFSTP innovations, and to reinforce the dissemination process, the Nuffield Foundation and the then Ministry of Education together organised a conference at the College of Advanced Technology, Loughborough, during the schools' Summer vacation 18-26 August 1964. Throughout, the conference emphasized practical techniques to assist teachers in the school trials. The project Organizers and Area Co-ordinators (Team leaders) were on hand to provide support and inspiration.[135] Considerable help was also received from HMI scientists, particularly Dick Long. In the planning stage, however, Long was worried that officers at the Nuffield Foundation felt a lack of confidence in HMI support. Becher's forthright reply cleared the air: "Your [Long's] suggestion that we see H.M.I.'s chief value at Loughborough in the cloak of respectability they bring with them is both unfair and absurd.....We do not want the Ministry to "rubber stamp" or "sell" any of our detailed proposals as opposed to our general approach. The various materials are not at present in a stage in which it would be remotely appropriate to give them blanket approval. Equally, however, we do not want detailed public criticism of them to be made before they have been tried out systematically....It would be sad - and perhaps even disastrous - if the teachers at Loughborough went away feeling that the Ministry altogether fails to share the fundamental conviction which lies behind the Nuffield project."[136] The Loughborough conference was a huge success for those teachers present:

> "[At Loughborough] It was the mood - the sense of high endeavour - it was also that people really believed that they were in the presence of something truly innovative."[137]

The correspondence between Rogers and Wenham during 1964-65 indicates the anxiety felt by Eric Rogers in trying to organize NOP at such a distance. Rogers returned to London briefly in December 1964 and his meeting with Area Co-ordinators and NOP Organizers revealed progress on all fronts and he returned to the USA 'feeling happier'.[138] Rogers' plan was to spend a period of the summer vacation, late June to early August 1965, preparing all the NOP materials for publication:

> "My own picture ran something like this: that I would first work at feedback in a very rough way, then go through each year in turn with the feedback and other information, and write in the changes. If that really meant I have a long time table, either things are hopelessly wrong with the present edition or the changes are more than I expect to put in....As you [Wenham] know, my plan has been to live in Cambridge for the summer. I should want to minimize trips to Mary Ward."[139]

These plans materialized and Wenham, Rogers, Harding and two secretaries worked solidly in the first ASE Headquarters in Cambridge, editing and finalising most of the NOP materials (the notable exception being the Year Five guides, which were later edited by Rogers back at Princeton). Roger's debt to Wenham is apparent in his hand written letter of 26 September 1965:

> "I believe you know how much I appreciated the magnificent loyal skilful work you did all through the past summer ... Your tremendous travels to and fro - always there when you promised - holding things together, giving wise verdicts, keeping perspectives, physics and publishing in harmony somehow (and of course people too) - has left a wonderful record ... The summer was a strain in a number of ways - some of which I hope you will never know - but it was a noble summer together, productive however ragged, and well worth it."

The Nuffield Foundation's own publishing machinery, directed by William Anderson, expected to publish all the O-level materials on 5 May 1966 but the size of the task resulted in a slight delay. The books were launched at a press conference on 27 June 1966. Representing the NFSTP was the Director, Brian Young, the Co-ordinators, John Maddox and Kevin Keohane, the O-level Organizers and their deputies. Sir John Newson and Sir Edward Boyle attended on behalf of the publishers, Longmans-Penguin Books. A torrent of debate accompanied the publications and the next five years witnessed an explosion of articles dealing with the Nuffield O-level projects.[140] *The Times Educational Supplement*, 5 May 1967, devoted eight pages to the 'Future of the £1,333,000 Revolution'.[141]

Woolnough's review of school physics teaching, 1960-85, analyses the NOP course in detail. He identifies six 'themes' weaving their way through the course, all of which find echoes in NAP:

1. The content and structure of the course (not a syllabus) and the unifying themes found in properties of matter, waves and oscillations, energy and fields, and the modern quantum ideas.
2. Teaching physics for understanding and the 'special' NOP examinations.
3. The emphasis on practical work - learning through doing and the pupils being active in their own learning.
4. The production of a logical and lucid teaching scheme designed to help students acquire knowledge through experiments and demonstrations.
5. The use of the students' own language in learning.

6.The use of the teachers' guides and guides to experiments (for many teachers these books formed the basis of a highly prescriptive series of experiments and demonstrations, the antithesis of the project team's intention).[142]

Throughout the review Woolnough makes repeated reference to the influence that the NOP course, its apparatus and its remarkable development team have had on school physics, despite his view that NOP was the last death throe of academic physics, rather than a useful staging post towards science for all.[143] Ironically, just as NOP was published a new Labour Government came to power and introduced comprehensive schooling and the CSE examination. These changes left NOP behind rather than ahead of movements in school science towards integrated and coordinated courses.

The Nuffield Trustees were, of course, aware of these changes and had set in motion their own plans to provide science courses for the wider ability range in comprehensive schools. Furthermore, in October 1965 the Trustees agreed to Maddox's request to consider administrative procedures to deal with the continuing revision of the O-level materials to meet the changing demand:

> "When the [O-level] books come on the market, therefore, the payment of the initial publication costs [£600 000] will be a first charge on the proceeds from the sales. A second and equally important charge will be for the costs of revising the materials for future editions: you [Wenham] may like to know that the Co-ordinator will be setting up in each of the subjects, chemistry, physics and biology, a committee to provide the Trustees with advice on the revision of the books now being printed and, in particular, to consider what kinds of revision are necessary, and when."[144]

Both Rogers and Wenham were appalled at this suggestion and strongly opposed such a committee. They believed in a good confident trial of the NOP materials and pointed out that the first students to complete the course would do so in 1969 and that it would be premature to consider a revision before 1970.

In the event, Maddox resigned as NFSTP Co-ordinator in June 1966 and the issue of an immediate O-level revision was shelved. However, upon Rogers' retirement from Princeton in 1971 he agreed to organize a major revision of the NOP materials and, once again, asked Ted Wenham to act as joint General Editor. The slow reorganization of the NFSTP, and its metamorphosis into the Nuffield Chelsea Curriculum Trust (NCCT), took place at the same time as the revisions to the Nuffield O-level courses . The disruption of the NFSTP administration and financial provision, which occurred throughout the 1970s, together with personnel problems caused by illness and death, resulted in prorogation for Revised NOP.[145] By the time the Nuffield A-level projects were due for revision the NCCT had been established in principle and an administrative framework was in place. Consequently, the A-level revisions proceeded smoothly and on schedule .

Nuffield O-level Physics, and its revision, evolved in an erratic manner and was dominated by the brilliant, idiosyncratic personality of Eric Rogers. Many people, such as Ted Wenham, John Lewis and Derek Harding, worked very hard to keep the project on course and successfully to install the teaching methods, physics content, apparatus and examinations into schools. It is clear from the literature that the NOP course has initiated considerable long-term debate about the nature of physics education, and science education in general. Many of the ideas that surfaced found their way into the second phase Nuffield schemes, in particular Nuffield A-level Physics.

Part III: Nyholm's Network and Mott's Matrix - the inception of Nuffield A-level Science.

The turbulence for the O-level physics project, in the spring of 1963, forced the Directors of the Nuffield Foundation to re-assess resources and begin to formulate plans for Nuffield A-level science. In April 1963, extended secondments (until September 1964) were arranged for a few selected team members to complete the O-level work and who, later, might become involved in the A-level phase: "Finally it has become apparent that the content of the course in the Fifth Form is likely to interact very closely with any work which might subsequently be done on the teaching of physics to the Sixth Form specialist. Apart from other considerations it seems sensible on grounds of economy of effort alone to devote some attention in the present enterprise to the groundwork for a new Advanced Level course."[146]

In an historical exploration of the link between school science and technology, McCulloch et al. insist that "...advisers and organisers of the science teaching project [Nuffield O-level] were also eager to develop programmes in the area of Advanced-level science."[147] Organizers in the O-level physics section did not make any formal appeals for a Nuffield A-level physics course. Rogers, Lewis and Wenham steadfastly maintained that "...it would be perfectly possible to teach any of the current A-level syllabuses after an O-level of the Nuffield variety."[148] If consulted, Rogers would have supported the development of an A-level course because O-level teachers needed such an A-level to understand the O-level physics course.[149] Wenham and Lewis felt that an A-level project must eventually follow NOP and they discussed their possible involvement and who might eventually concert such a programme. But at no stage did they force the Foundation's hand.[150] Their time and thoughts were fully occupied with NOP. Alternatively, there is evidence that Halliwell did press for an A-level chemistry project to satisfy the schools' perceived need for Nuffield A-level materials. But this occurred much later in the development of the Nuffield A-level physical sciences.

It is clear, however, that university advisers on O-level Consultative Committees, particularly Professors Mott and Nyholm, were most anxious to elevate the NFSTP into the A-level arena. A coordinated appeal was prepared for the Trustees by the three Consultative Committee chairmen during September 1963. Mott had consistently expressed his interest in academically able scientists and in the A-level curriculum.[151] Earlier discussion involving Mott's influence within the National Committee on Physics Education had pointed to his expertise in the relationship between school physics and university physics, or, in more modern parlance, the school-university interface.[152] Of course, at this time A-level syllabuses were designed in the first place for the physics specialist. Nyholm's interest stemmed, primarily, from his influential role as Moderator in Chemistry for the University of London's A-level GCE examinations. In the early 1960's, Nyholm ordered a complete re-appraisal and concluded:

> "No doubt there are points of detail - and maybe of principle - which one might question, but the overwhelming view that we need to modernise both our syllabuses and examinations must give us cause for self-examination, if not alarm."[153]

The Trustees, while being impressed by their Chairmen's views, were worried about an increased allocation of funds: "They [the Trustees] appreciated that, although this extension of the project would not be quite so costly as the 'O'level programme, it would, nevertheless, be a major undertaking."[154] For example, Eric Rogers reported that the Foundation had poured a large amount of money into arrangements for a few preliminary trials: "...about twice as much money as they expected for apparatus to enable schools to try following the suggested programme closely..."[155] The Trustees conceded, however, that it would be difficult to find another independent, kindred organization to carry out the necessary development work at A-level.

Further lobbying took place at a Nuffield dinner party held on Monday 18 November 1963 and attended by Sir Hector Hetherington and Lord Todd, from the Trustees, and senior personnel from the NFSTP. Tactical letters were exchanged between Becher, Mott and Nyholm. For instance, Nyholm suggested that an opportunity be found for a private talk with the Trustees, but without the O-level organizers being present. He wanted to explain that a failure to extend the project would result in a waste of money and a waste of some people's time.[156] Becher thought this an excellent idea:

> "Perhaps the best thing would be for myself and the organizers to turn up rather after 7 o'clock so that you can tackle our trustees privately first; and I will arrange to lay this on... In general, I am

> inclined to think that the tactically wisest move might be to present the A-level venture as initially a pilot study of the requirements rather than a fully fledged curriculum development programme: though such a pilot scheme could, of course, become, in practice, almost indistinguishable from a fully fledged attack on A-level."[157]

Hetherington and Todd impelled further discussion at the Trustees' next meeting and eventually there was agreement "...to the continuation of the present work to cover science at 'A' level for intending future specialists."[158] Furthermore, the Trustees decided to leave aside for the time being the question of science for non-science sixth-formers.

Tentative plans concerning timing, policy and staffing were endorsed at the Trustees meeting on 17 January 1964:

1. The time table of the A-level should dovetail with the O-level section and any A-level materials should be made public for the 1968-9 school year.

2. There is a need for liaison with university science departments and for preserving close links with the schools and other groups concerned with educational policy. The Foundation anticipates very close links between the three branches of science e.g. both the physicists and the chemists are thinking of a common course which would encompass the structure and properties of matter, the atom and the molecule and, in general, common ground in the subjects.

3. Professors Mott and Nyholm were appointed co-chairmen of their respective physics and chemistry working groups. The Trustees allocated £18,000 for the cost of all three study groups.[159] Peter Kelly, a member of the O-level biology team, and, later, Bunny Dowdeswell, the Organizer, were enlisted as Joint Organizers for the A-level Biology programme.[160]

By now the Nuffield Foundation had pledged to enlarge the NFSTP to include primary school science, science for the secondary modern schools, as well as the proposed A-levels. Further frank discussions were held at this January meeting, about the Foundation's own internal administration. Farrer-Brown had recently indicated his wish to retire from the Directorship. Becher, his Assistant Director, had noticed the increased problems posed by the NFSTP, "...and even within the first year of effective operation it has taken up more time for the Foundation's staff than any previous project."[161] Moreover, the NFSTP had become a complex field of overlapping and interrelated schemes and needed to be intelligently tied together. Becher argued that the Trustees should appoint a full-time coordinating organizer for the NFSTP and run the scheme as a temporary independent organisation in its own right for, say, five years. The 'paragon' appointed must have three essential qualities:

- a sound scientific background to discern inconsistencies in the draft materials;
- good administrative qualities to help relieve the burden from the Foundation and the subject organizers;
- ability to deal with problems in human relations both inside and outside the NFSTP.

Finally, he recommended that the NFSTP should move away from the overcrowding in Nuffield Lodge and occupy premises in Mary Ward House, 5-7 Tavistock Place, London.[162] Becher's persuasive logic convinced the Trustees that such a coordinating post was necessary, possibly at Assistant Director level.

For some months, Becher and Mott had conducted an active correspondence, searching for a physicist to succeed Eric Rogers on the O-level project and, possibly, share responsibility for the pilot scheme in A-level physics. Mott had circulated a letter to his colleagues in university physics departments and had followed up a number of possibilities. In one of these exchanges, Mott raised the question of 'the Assistant Director':

> "Do you think it would be useful to consult a first class scientific journalist like John Maddox? He is, of course, a trained scientist, very intelligent and knows everybody."[163]

Next, Mott arranged an exploratory meeting with Maddox and then wrote to Farrer-Brown strongly supportive of Maddox's application and, hopefully, appointment.[164] In all this, Mott had cleverly seen a solution to the dilemma posed by Eric Rogers' return to Princeton in September 1964: "My feelings about the future of the Project [NOP] depend on what happens about Maddox."[165] At the end of March 1964, John Maddox was interviewed by the Trustees and soon afterwards was appointed Co-ordinator of the NFSTP, at the appropriate rank of Assistant Director. Mott and Maddox were now able to provide NOP with some long-term organizational structure.

Among a host of replies about replacements for Eric Rogers, Mott had received a recommendation about Derek Harding, a physicist at St. Paul's College, Cheltenham.[166] Harding's one-year release was arranged from September 1964 and this enabled Maddox to propose the following O-level organisation:

- Professor Eric Rogers would remain as Organizer and would return to the UK in the summer vacation to complete writing the Teachers' Guides;
- John Lewis would remain an Associate Organizer based at Malvern and maintain responsibility for equipment;
- Ted Wenham, promoted to Associate Organizer, would direct the work of the team leaders and provide overall 'inspiring and cementing drive';
- Derek Harding, as Assistant Organizer, would work in London analysing and channelling the feed-back from the trials schools.[167]

During these opening months of 1964, Mott was also setting up his A-level physics working party. Eric Rogers, living in Hove, Sussex, discussed these developments with Professor Roger Blin-Stoyle and Dr.A.D.C.(Sandy) Grassie at the University of Sussex.[168] The university physics department had helped develop a first year course on the structure and properties of matter and Grassie had been teaching the course. Eventually, Professor Blin-Stoyle, in consultation with Professor Ken Smith, agreed to Grassie's half-time secondment to the NFSTP.[169] Twenty years into the future Blin-Stoyle will also find himself embroiled in curriculum renewal in schools and its effects on universities and Ken Smith will take over Mott's role in the revision of Nuffield A-level physics. The final composition of Mott's group was: E.S.Shire, Cambridge University; A.D.C.Grassie, Sussex University; V.J.Long, HMI; J.L.Lewis, NFSTP. Nyholm's parallel chemistry group consisted of D.J.Millen, University College London; Professor J.Lewis, University of Manchester; H.F.Halliwell, NFSTP; J.E.Spice, Winchester College.[170]

As a vehicle to facilitate an understanding of the attitudes towards A-level science in the early 1960's, and Mott and Nyholm's initial desire to plan an integrated physical science project 'as suggested by Spice'[171], it is necessary to record some of the influences that provoked John Spice to publish his *Structure and Properties of Matter* (SPM) course.[172]

In 1959, Dr.John Spice[173] joined the science staff at Winchester College after 14 years as a university lecturer at Liverpool. He was immediately struck by how little school chemistry and physics had changed in the years since he had left school. Furthermore, he was concerned at the way 'very bright boys' were 'bled-off' from the chemistry course to study double mathematics. Fortunately, Spice's headmaster at Winchester, Sir Desmond Lee, was amongst a number of public school educationalists pushing for a reform of both the content and subject specialization found in the usual three A-levels.[174] At this time, Lee was a member of the Secondary School Examinations Council (SSEC). This advisory body had been consistently warning Ministers of Education about the dangers of over-specialization in the sixth form.[175] But government ministers, at that time, could only advise schools. The schools, themselves, could not make changes because "...they are tied to the syllabus and curriculum required to get university places; the universities will not initiate changes, partly because they do not regard it as any part of their function to control the curricula of schools, partly because they do not directly control the examinations, partly because...they have no machinery for arriving at and enforcing a common decision on such issues."[176]

The Trustees of the Calouste Gulbenkian Foundation did not assume the role as 'agents for change' but they regarded these issues as sufficiently important to finance three widely reported initiatives to promote change. In September 1959 the University of Birmingham published an enquiry into A-level physics, chemistry, biological sciences (biology, botany and zoology), geography, geology and mathematics (several subjects) syllabuses.[177] The subject panels found that "... the balance of subjects is distorted more heavily towards specialist subjects than the school time-table shows, because of the time spent on homework in them."[178] In particular, the physics panel proposed a reduction in the syllabus to release 10-15 per cent of time for general education purposes. Also, they recommended a 'New level' physics syllabus intended primarily for students who did not intend to specialize in one of the physical sciences: "The syllabus proposed attempts to bring before the candidates, in a non-mathematical way, some of the achievements of modern physics and its inter-relations with other subjects."[179] Overall, the Birmingham syllabus changes did not radically alter the traditional approach to physics: acoustics, heat, light, electricity and magnetism, Newtonian physics and a practical examination.

Secondly, the SMA/AWST A-level physics syllabus, first distributed in December 1959, also reduced the 'width of factual knowledge required' and "...regrouped the subject matter as a whole in an attempt to show how physics is regarded to-day."[180] Inevitably, this syllabus was heavily influenced by Lewis, Boulind and Elton. And finally, in April 1960, the Oxford University Department of Education, led by A.D.C.Peterson, reported to the Gulbenkian Foundation on *Arts and Science Sides in the Sixth Form*. This highly critical analysis produces a sense of anomie - the reader is wrenched from the familiar and thrown into challenging new surroundings. The Oxford report reinforced the view that subject specialization allowed little, or no, time for a balanced A-level curriculum. Overall, it recorded considerable difficulties and despair:

> "Our survey has disclosed that there is at present no body which has both the power, the machinery, and in its own view, the competence, to make changes possible."[181]

While serving on the SSEC, Sir Desmond Lee was often reminded of the origins of the Oxford survey, the 'two cultures' gap, when discussing science syllabuses and examinations like those proposed for the Studley Experiment . He felt a sense of unreality as he realized that, as a classicist, he was being lectured on modern physics by a nun, Sister St.Joan of Arc.[182] In order to keep in touch with developments, Lee recommended John Spice's appointment to the SSEC's Science Panel. With additional support from Winchester's Headmaster, Spice prepared a combined sixth form physics and chemistry course which, he felt, could help alleviate some of the problems of over specialization. Spice circulated his paper to Mott, Nyholm, University Departments, HMI and to other headmasters known to be interested.[183] He received many encouraging replies and decided to publish an article, "Sixth Form Science: A New Proposal", in the Times Educational Supplement, 7 June 1963.

Believing in its own 'power, machinery and competence' the Nuffield Foundation had decided to investigate ways to change the sixth form curriculum through Mott's and Nyholm's pilot study groups. Nyholm's initial interest in Spice's proposals is well documented, so on 8 June 1964 he arranged for Spice to explain the SPM course to the A-level chemistry group.[184] Soon after this, Mott's A-level physics group met at Caius College, Cambridge, on 27-28 June. Mott invited Professor Nyholm, Millen and Spice from the chemistry group, the O-level organizer, Eric Rogers, and Dick Long, HMI, the convenor of the SSEC's Science Panel. In setting up the framework for discussion, it was decided that any A-level courses should be designed for a two-year sixth form and that the "...present extent of sixth form specialization should not be increased."[185] Attention centred once again on Spice's SPM course, now re-titled Physical Science (PS), and most delegates found it difficult to decide which topics to leave out. Initially, it was decided that the PS course would represent 1.5 A-level subjects and so the discussion turned to possible half subjects, forerunners to today's AS-level syllabuses.[186] Half-subjects mentioned were applied mathematics, or ancillary mathematics.

Spice's proposals received strong support from physicists like Mott, Lewis, Grassie and Long: "I [Long] harp on the need for building physics and chemistry together at A-level."[187] In contrast, however, the forthright Eric Rogers began a stout defence of physics and expressed his doubts about the PS approach:

> "...his [Spice's] programme for a combined A-level Physical Science is clever and may be the wise solution for Pre-Medicals, Biologists and others. But I do not share the happy glow that V.J.Long and John Lewis and others share over Spice's proposals. His attitude to physics (even more strongly in the original draft) is a very odd one that can wreck Physics. He treats it as a handmaiden of techniques for Biology and Chemistry, regards physicists as playing with details of behaviour and offers Chemistry as the fundamental body of knowledge which, instead of Physics, will explain physical behaviour."[188]

The inimitable Rogers countered the PS proposals with a personal view that chemistry was still a largely empirical and qualitative science with "...the lingering smell of hydrogen sulphide and the use of retorts clearly in his [Rogers'] mind."[189] Rogers has arrived at this meeting in a deliberately provocative mood. Spice recalls that most of those present simply listened in silence. But when Rogers implied that chemists were not interested in accurate measurements, Nyholm replied angrily "....that when he was working in Sydney the most precise potentiometer in the whole university was in the physical chemistry department, and that physicists often came to make use of the instrument."[190] Rogers' rather unpleasant attack provoked considerable anger in Nyholm.

Later, Nyholm was anxious to play down this rivalry: "We believe that at this important stage in the development of the A-level work chemists and physicists will need to co-operate to the maximum and a lot of give and take will be required."[191] Nevertheless, Nyholm was determined to take a strong line: "Keen as I am on S.P.M., I would hate to see a merging of chemistry and physics...until I was sure that they [physicists] understood a little more of what chemistry is and what it tries to do."[192] But Rogers' actions must have diminished Nyholm's euphoria for an integrated physics and chemistry project to lead the attack on A-level curriculum renewal.

Within a few months Nyholm would insist that separate chemistry(NAC) and physics(NAP) projects be developed alongside a PS course (NAPS).

At the end of this uncomfortable meeting a number of procedural matters were arranged. Professor Mott agreed to lead a sub-group to consider the chemists' need for atomic theory leading to orbitals to emerge quite early in their A-level course. Sandy Grassie undertook to carry out a study of heat and thermodynamics, leading to chemical equilibrium and reaction kinetics.[193] Spice and Grassie would continue to work out details of a PS syllabus. Drawing on his extensive experience of A-level science Dick Long prepared a concomitant paper explaining the rapidly changing nature of sixth-forms and the resultant wider spread in academic ability. He listed some consequences for any Nuffield A-level work:

1.An A-level course must be used for some 'vocational training' and should also be concerned in giving students understanding.

2.Any course must be 'adaptable' to the needs of all pupils but it must also satisfy people with 'academic inclinations'. Such courses should be like a 'skeleton to which ribs can be added'.[194]

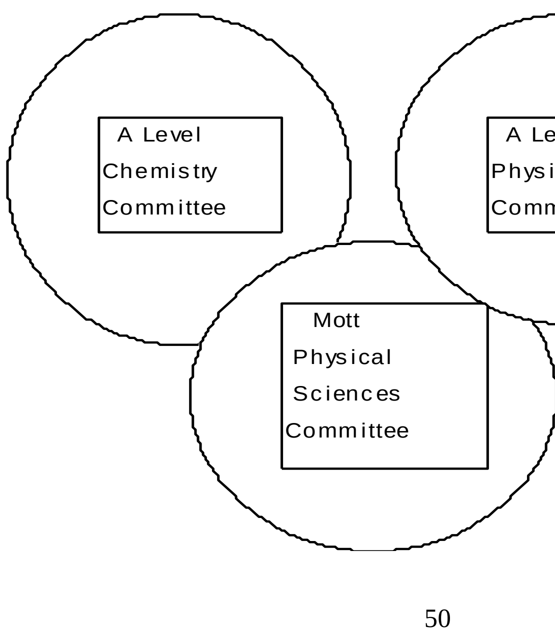
During the remainder of 1964, Mott, Nyholm and Maddox arranged a number of physical science meetings to monitor progress and finalize policy.[195] Maddox began to coordinate all the ideas and prepare detailed proposals for the Trustees' meeting in February 1965. He also began a survey of personnel who might be available in 1965-6: Coulson, Lewis, Wenham, M.S.Smith, Halliwell, Spice, Grassie and R.D.Harrison.[196]

The document for the Trustees, signed by Mott, Nyholm and Maddox, supported the educational value of a fusion between physics and chemistry. They listed objections to such a PS course as coming from specialist teachers of physics and chemistry and from the universities. Furthermore, they noted that the merits of such a PS course would need to be thoroughly demonstrated in school trials and in A-level examinations. Aware of the needs of O-level pupils in the Nuffield trials schools, the co-chairmen requested that the Foundation should "...open negotiations with the Secretaries of the Examinations Boards to arrange for the revision of the existing A-level syllabus in the light of the new teaching materials."[197] The overall organization of the PS programme would depend on a joint chemistry and physics consultative committee, with Mott as Chairman and Nyholm as Vice-Chairman. Appendices to the paper listed a possible membership of this consultative committee, a draft policy statement committing the Foundation to A-level work in physical science and, finally, details of the combined course prepared by Spice and Grassie. Financial arrangements had been agreed on the assumption that combined courses in Biological Science (Botany and Zoology) and Physical Science (Chemistry and Physics) would be prepared:

A-level Biological Science	£135,635
A-level Physical Science	£155,610

In an unexpected and retrocedent move, Nyholm wrote to the NFSTP just before the Trustees' meeting expressing his doubts about the PS course taking priority over separate chemistry and physics courses.[198] Needless to say, this generated a strong reaction from Maddox, who suggested that Nyholm would have to 'argue his case' at the next joint A-level Physical Sciences Committee meeting, scheduled for 22 March 1965.[199] For some time a number of the chemists, Halliwell in particular, had been worried that the traditional A-level syllabuses would not suit the increasing numbers of Nuffield O-level students wanting to do A-level chemistry.[200] Halliwell felt that it would be wrong to present these students with a choice of either PS or a traditional A-level.[201]

Further discussions at the British Committee on Chemical Education during February forced Nyholm to the conclusion "...that a combined physical sciences course is not an objective that can be attained in the immediate future, though we still feel that it should be a long-term aim."[202] In the short-term, 1965-1968(?), Nyholm requested that the Trustees establish separate Nuffield A-level Physics (NAP) and Nuffield A-level Chemistry (NAC) projects and that in five to seven years' time a physical science course (NAPS) would emerge with its structure determined by wide discussion. He also suggested that two extra consultative committees be set up to overlap Mott's joint committee:[203]



Norman Booth, an HMI and member of Mott's joint committee, supported Nyholm's position:

> "As I see it, the setting up by Nuffield of a Physics Group and a Chemistry Group gives time for the Physical Sciences Project to grow on people....I think it will take some time before the majority of schools turn over to physical science rather than separate subjects. Indeed, I think it may be some time for the whole idea of the acceptance of such a course to penetrate into the universities."[204]

University physicists involved in the O-level project also voiced their doubts about the PS course. The physics O-level Consultative Committee had not met for twelve months and so their tenth meeting, held on 9 November 1964, allowed discussion on the A-level proposals. The university representatives were irascible and felt strongly that the joint course would not be acceptable to universities, especially as a qualification for entry to an honours school. Professor Butler, who was also a member of the Schools Council, expressed the opinion "...that we do not really know what is wanted at A-level....and hoped that the new Schools Council will help define the problem."[205] Eric Rogers, though not at this meeting, had expressed the view that at school level the overlap between physics and chemistry was not as great as that perceived by the university scientists.[206] Therefore, Professor Gunn was perplexed to hear that "...after the Scots had gone to considerable trouble to separate the courses [a joint science course] with great success, that we should now propose to join them."[207] The strength of university opinion took Maddox by surprise and he noted in a letter to Dick Long that something shall have to be done to disarm university opinion.[208] In fact, the full blast of university pressure was still to be felt in the Nuffield A-level programme and, incidentally, it would be Long who would feel its force.

The Nuffield Foundation, however, decided to delay a decision about the A-level physical sciences until the end of March 1965. The fledgling Schools Council had decided to hold its first conference, in conjunction with the NFSTP, at the University of Nottingham from 18-20 March 1965, to discuss the content of the sixth form science courses. Representatives from the NFSTP, and from the ASE's Physical Science Committee[209], spoke to delegates and the exchange of information provided valuable guidance in finalising a policy for the Nuffield A-level projects.[210]

Two days later Mott's joint A-level committee held a meeting at Mary Ward House to resolve their differences. The Nuffield Foundation's new Director, Brian Young[211], was in attendance and anxious to prepare a suitable policy statement for the Trustees' approval. Nyholm's proposal for three separate A-levels was agreed, but John Spice emphasized the need to give all three projects equal priority. The question of committee control, however, went against Nyholm. It was decided to reconstitute the chemistry and physics groups into a single consultative committee with Professor Mott as Chairman and Professor Nyholm as Vice-Chairman.[212] Finally, a carefully worded policy statement was prepared:

> "Accordingly, it has been decided to develop modern sixth form courses for teaching physical science (that is, physics and chemistry in combination), for teaching chemistry and for teaching physics. Equal weight will be given to these three objectives. The work will be carried out by an organization reporting to a single consultative committee to be known as the Joint Committee for the Physical Sciences."[213]

At this time 'equal weight' meant that only £155,610 was allocated to three projects in the A-level physical sciences, approximately £52,000 per project, or 8-10 person-years per project. This meant that the Trustees did not increase the overall allocation of funds available for these projects and this oversight caused desperate personnel shortages in employment of full-time staff. In turn, this resulted in delays in the publication of Nuffield Advanced Physical Science and helped focus the pressures, and generate communication problems, in NAP.[214] Two years later, however, after much discussion, the Trustees had to agree to increase the allowance to the three A-level physical science projects to £333,110.[215] This influx revitalized the ailing A-level projects. In comparison, development finance in the Nuffield O-level projects during 1963-67, for curriculum experiments, apparatus, materials and writing texts, was approximately: NOP - £158,000; NOC - £102,000; NOB - £120,000. These figure represent about 16.5 person-years per project and do not include publishing costs.[216]

CHAPTER TWO
University Liaison? - the resignation of the first NAP Organizer

The Nuffield A-level Physics project started much later than the other A-level projects. In NAB and NAC talented O-level team members, Kelly and Coulson, were promoted to the role of A-level Organizers, in the hope that continuity would be maintained between the two curriculum areas. The disruption caused by McGill's death and Rogers' appointment as NOP Organizer had created some upheaval for the physics section; the organization became scattered and there were, not surprisingly, some minor personality clashes between the team members and with the Co-ordinator, Maddox. So a fresh start was suggested by Mott and Maddox, who strongly supported Dick Long's appointment to the post of A-level Physics Organizer:

> "What I [Maddox] am writing about is the exciting possibility that suggested itself to me when you [Long] mentioned casually, that you would be retiring quite soon. As I said then and I say now, all of us would be delighted if we could persuade you to come here to run the physical sciences [sic] section of the A-level project when you retire or - if it is possible - a little before."[1]

Long had been the main HMI support behind the Studley experiment and as Staff Inspector for Science, had been in close contact with the NFSTP helping Becher and Maddox on a number of occasions in the political minefield of the O-level physics project. Furthermore, Long had been instrumental in implementing NOP in schools as an area co-ordinator for the York region. In an earlier communication Maddox had pointed out to Long the over-abundance of people available to help develop NAP, but that there was a 'desperate lack of a suitable organizer.' [2]

Long accepted the challenge and was seconded from the DES in September 1965 and in April 1966, upon his retirement, became the full-time A-level Organizer.[3] In his negotiations with Maddox, during the early months of 1965, Long mentioned that he might not wish to stay on as NAP

Organizer for the full duration of the project - he wanted to use his retirement to travel. Furthermore, Long was anxious to maintain his HMI independence until his formal retirement in April 1966: "I still want to keep my dealings with the Foundation out of the public eye, at least until after the A.S.E. Christmas meetings [1965]. I've still a first duty to the Department and having tried to serve it honestly for 17 years must do what I can to maintain H.M.I.'s pose. I know how news gets around - how quickly! - but that is different from public statement."[4]

Apart from the expediency of filling the position, the appointment of a 65-year-old HMI to the demanding post of NAP Organizer was not an obvious thing for the Nuffield Foundation to do. Wenham noted that at this time "...there was active distrust of the appointment of an HMI to the post."[5] Moreover, in March 1965 at a Schools Council conference on the teaching of science in the sixth form, Long had publicly supported A-level courses that explored the common ground in chemistry and physics and, in the interests of the less able student, he "...suggested two 'A' levels, one in breadth and one in depth. Both would be taken to obtain balance and vigour."[6] Long acknowledged that this would mean sixth formers arriving at the university with a very varied background of knowledge and that the universities might require 'levelling-up' courses and, perhaps, longer courses.

As it turned out, both Long's aversion to what he would see as premature public statements and the role of A-levels as preparation for degree work were to inhibit Long's role as NAP Organizer. In a little over 12 months, as conflicting impulses coincided, Long would be subjected to intensive pressure from university physics teachers, resulting in his resignation as the NAP Organizer:

> "The concerted objections of the university liaison representatives, however, compelled me to put my resignation in the Foundation's hands. If our plans were to go forward, they would need strong support."[7]

The history of the Nuffield A-level Physics Project is instructive as an example of the kind of partnership and the sort of co-operation, compromise and accommodation required for successful post-16 curriculum development. In this light, Presseisen, and other writers in this field, point out that an analysis of the patterns of consistency and change that occur over time are needed to uncover the 'unlearned lessons' in educational reforms, like those carried out under the NFSTP's umbrella. So first, then, it is necessary to record the detailed events, Presseisen's 'historical underpinnings', which eventually led to Long's resignation.[8]

In order to get the A-level physics project off the ground Maddox and Long arranged an inaugural conference at Malvern, during 20-24 August 1965. Members of Mott's pilot study group and other 'old hands' from NOP were invited to submit their ideas to the NFSTP within a month.[9] Soon after this meeting Long fell ill with an extended dose of shingles, but was still able to joke to Maddox that his next career would be a valetudinarian. Despite his discomfort Long managed to outline his seminal ideas about the NAP. He published his first paper in November 1965 and it is interesting to note how many points are included in the 1971 published version of the course. A summary of his thoughts are listed below:

> “1. An A-level course must be flexible enough to give potential academics something to bite on, and yet suitable as a sixth-form subject for those who will not become career physicists.
>
> 2. The scope of the present A-level physics syllabus is satisfactory, but the manner in which physics is taught leaves a lot to be desired.
>
> 3. Mathematics is an essential component of physics, and should be introduced early enough for it to be used as a tool throughout the course. It follows that there must be a supplementary mathematics course for those not reading A-level mathematics.
>
> 4. Electronics is also a necessary tool for a physicist. But this is best learned by practice and not from the blackboard.
>
> 5. Practical work should, wherever possible, include an element of design. At least some of the A-level course - say 10% - should be given over to project work, usually in electronics." [10]

Following the Malvern Conference, work began in earnest on the production of materials. As well as Long, who was based in York, Bill Trotter and Martin Harrap worked for the project full-time from September 1965. A number of other people were involved under various part-time arrangements. Bryan Chapman and Roger Harrison, who like Long had both been area co-ordinators for NOP, contributed as part of the research element of their posts in higher education. Ted Wenham, Geoffrey Foxcroft, Mike Smith and Dick Longhurst were allowed time by their employers to participate when available. This team began to develop Long's ideas into a coherent course and sixteen preliminary schools were selected to try out the draft materials.

Long was also anxious to expand the project's horizons: "At the next meeting I would like to have almost all new people, mostly from state schools, and put before them the kind of work we are aiming at and inviting them to try their hands at writing. In this way I hope to discover people we ought to invest in."[11] He arranged a second A-level conference from Friday 29th October to Monday 1 November 1965 at Mary Ward House, inviting school and university physics teachers, both male and female.[12]

As a result of these meetings papers and ideas were arriving on Long's desk in an ad hoc manner from many sources. Of importance was a stimulating contribution from Jon Ogborn, recently appointed by Wenham at Worcester , about energy levels in atoms and the graphical solution to the Schrödinger Equation. These ideas would eventually be incorporated into the published NAP course as Unit 10: *Waves, particles and atoms*. Long was sufficiently impressed to consider these ideas as an 'end-point' for his course. However, he provided a cautionary note that the ideas might be beyond the teaching powers of many teachers and that, at the same time, "...our duty to the engineers is not to be overlooked and interesting as this work is to them it hardly represents what they want us to attend to. I don't think we can afford to spend all our time on atomic structure, for all its fascination and modernity."[13] Long's inclusion of 'advanced ideas' into the NAP course was intended to create interest amongst the A-level students as well as a means to demonstrate the essential nature of physics. These ideas would eventually focus university criticism on Long's A-level course.

From the beginning Dick Long adopted a different organizational structure to the other A-level projects. He did not wish to set up working parties of practising physicists and teachers in the same way as NAC and NAPS. Also, Long employed more part-time team members, no doubt because of the financial restraint felt, initially, by all three physical science projects. Dr. Frank McKim, from the NAPS project, attended NAP meetings and felt unhappy about the way the physics team was working. Firstly, he observed that there was a reluctance by Long to circulate documents, even to his team. In addition, discussions at NAP meetings concentrated on papers produced by Long himself and McKim was critical that NAP team members, at this stage, were not given responsibility for authorship. He felt that this was a legacy from Eric Rogers' style in the NOP project.[14]

In preparing the materials Long accepted Eric Rogers' NOP principle that a new idea had to be introduced casually at first, then rigorously later, and thought it best to distinguish between the two years of the course. By February 1966 Long was ready to publish his 'skeleton outline' of a course, noting that such a list can be easily misread. Long was anxious that the team's plans for a relevant and coherent course should be taken into account. At this stage his course had little substance and was based on a series of unedited, and often handwritten, set of papers by a wide range of interested physicists. Furthermore, Long was aware that this course would need modification in the light of school trials:

> "Let us write some programmes and test them on some average sixth-formers, noting all deviations. On these we decide whether to amplify by writing in, to simplify by expunging, or to scrap."[15]

Both the individual 'units' and their distribution into each year would be heavily influenced by the trials.

Criticism and comment were never far away. For example, Ogborn and Wenham, then on the periphery of the NAP developments, were very critical that Long's first papers on electricity were too detailed: "We suggest that "growing acquaintance with ideas" which is the essence of effective understanding and upon which the "O" level programme places so much emphasis, is being forgotten....We think that there is a need for more consideration of lessons which look at the shape of things past and to come."[16]

Prompted by Mott and Maddox, Long was also asked to liaise with university physics departments. So, at a very early stage in the NAP planning, the Physics Department at Manchester University, at the suggestion of Professor B.H.Flowers, was canvassed for its views on Long's outline plan for NAP. There was general agreement that a course could be based on atoms. molecules, electrons and electromagnetic fields "....and that this would not be more difficult that the present set-up, and would certainly be more exciting."[17] In order to involve more university departments Maddox suggested that an extended meeting be arranged to inform the universities about NAP and to seek their opinions about materials being produced. The NFSTP held a discussion session on 3 March 1966 at Mary Ward House in London and, in the evening, arranged a working dinner at the Russell Hotel. Unfortunately, this meeting was not followed up and in June 1966 Maddox, and the newly-appointed Co-ordinator, Professor Kevin Keohane , reported to Long that "....the Vice-Chancellors' Committee have said that they are uneasy about the lack of information on the physics course and the physical science course, and some university departments, like Manchester, are saying that they are being asked to sign a blank cheque."[18]

AN OUTLINE OF THE FIRST NUFFIELD 'A' LEVEL PHYSICS PROJECT ORGANIZED BY V.J.LONG

21.2.1966.

1. **Properties of Matter**
   a. Problems of structures. Introduction only to mechanics of structures.
   b. Nature of materials. Emphasis on metals. Elastic properties, conductivities, bubble raft, introduction to X-ray analysis.
2. **Electrical Networks**
   a. House wiring practice.
   b. Practical units and measuring instruments.
   c. Deviations from Ohm's Law, thermistors, etc.
   d. Semi-conductors, simple hole theory, transistor as amplifier and switch.
   e. Static charges, capacitors, energy.
3. **Dynamics I**
   a. Kinematics and momentum, using calculus, energy.
   b. Simple harmonic motion, using calculus, energy.
4. **Dynamics II**
   a. Rotation, energy, moment of inertia but only calculation for disc on axis, rotating machinery.
   b. Angular momentum.
   c. Optional, gyroscopes.
5. **Electric field**
   a. From uniform field (parallel plates) to radial fields.
   b. Rutherford scattering.
   c. Elementary discussion of quantised ground state, using Frank Hertz.
   d. Charging and discharging condensers, exponential function, integrating and differentiating circuits.
6. **Magnetic field**
   a. Little attention to permanent magnets, ferro-magnetism, or magnetising force.
   b. Electromagnetic induction.
7. **Gravitational field**
   a. Recap on O-level course, satellites, life on the moon, "weightlessness".
   b. Optional, tides and bores.
   c. Gravitational and inertial mass.
8. **Harmonic Oscillator**
   a. Electrical, very slow A.C., lag and lead, maintenance by transistor.
   b. Audio frequency, so to mechanical oscillators, various.
   c. Mathematical statement.
   d. Free and forced vibrations, transient conditions, resonance, quality factor. Little mathematics here, mostly observation of phenomena.
   e. Optional, mathematical treatment of project.
9. **Electromagnetic radiation**
   a. Radio frequency oscillators, VHF oscillations, centimetre waves, visible light. Common properties.
   b. Revision of physical optics as necessary, interference, diffraction, polarisation.
   c. Introduction to transmission along parallel wires, extension to waves in vacuo and a value for velocity.

10. **Spectra**
  a. Emission spectra, absorption spectra.
  b. Quantisation of radiation.
  c. Further speculation on atomic structure.

11. **Relativity**
  a. Velocity of light and other elecrtomagnetic radiation.
  b. Simple argument for i. decrease in length
  c. Simple argument for ii. dilatation of time
  d. Simple argument for iii. increase in mass
  e. Pressure of light.
  f. Optional section on a treatment of electro-magnetism involving relativity.
  g. Nuclear fission and fusion briefly.
  h. Interlude on the nature of units and the reliability of constants.

12. **Continuous v Particulate Theories**
  a. Interlude on hydraulics to show how far one can go with a continuous fluid theory. How briefly.
  b. Discussion (brief) of particle model of liquid, surface tension, viscosity.
  c. Recap evidence for particulate nature, from chemistry, from electricity, from photo-electricity.

13. **Thermodynamics**
  a. Discussion of energy changes with qualitative notions of entropy.
  b. Minimal justification of the measure of entropy.
  c. Association of entropy with disorder.
  d. Something on Boltzman distribution.
  e. Recap nature of a gas.
  f. Optional, study of weather.
  g. Optional, something on aerodynamics.

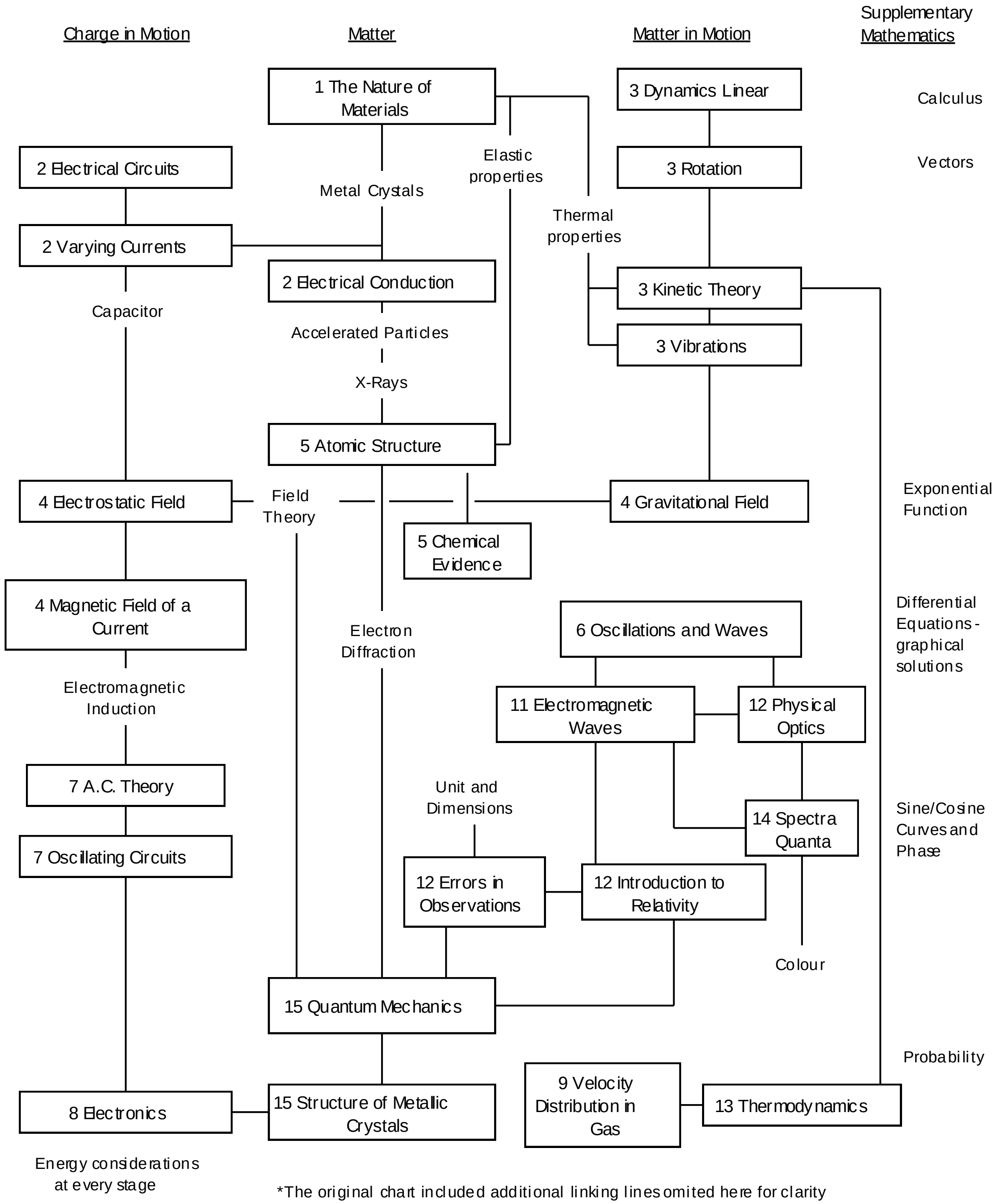
14. **Conduction in Metals** (and other media? Something on electrolysis?)
  a. Quantum states in metals - if possible.
  b. Work function.

15. **Elements of digital computing** (optional?)
  a. Binary scales
  b. Unit transistor elements.
  c. Minimum number of gates.
  d. Simple addition.

16. **Atomic Structure**
  a. Radioactivity.
  b. Recap of evidence for nucleus, proton, neutron.
  c. Periodic table interpreted in terms of atomic structure.
  d. Something on the nucleus and other particles?

17. **Wave/particle duality**
  a. Electron diffraction.
  b. Matter waves.
  c. Compton effect.
  d. Uncertainty.

Figure 1
Links in Long's Nuffield A-Level Course*
(Numbers refer to initial writing sections)



*The original chart included additional linking lines omited here for clarity

V.J. Long
Jan. 1967

60

In contrast, Professor Allanson of Birmingham University argued in the first publication of Physics Education that: "The Nuffield Project [NAP] is frankly experimental and is being conducted on a small scale. As such it can command the good will of the universities."[19] Within a few months of this comment the good will turned sour, ironically at a meeting chaired by Professor Allanson.

In order to involve university personnel at the development stage of NAP, Keohane took up Maddox's idea of a university advisory panel, supplementary to the Consultative Committee, to help the physics project team. Long had serious misgivings about the timing and the nature of this involvement with the universities. He was well aware of the difficulties which would follow a premature release of a partially formed course to the perspectives of university departments. While not adverse to consulting university physicists he knew to be familiar with the characteristic approach of the project team, Long was anxious to avoid sparse descriptions of the work, without adequate explanation of its educational background being misinterpreted by the universities. He was to write in June 1966:

> "It would be easy by means of a syllabus to give a very false impression of what we are attempting to do. Some of the items in our lists are to be dealt with in so casual a manner, as a first introduction to the ideas for immature people, that the universities would probably repudiate them altogether....It is evident that the universities are much more interested in the content of the course than our other thoughts about the teaching methods."[20]

Nonetheless, he had provided a syllabus to send to universities, although he referred to it directly as 'a poor thing' and was actively working on a more detailed document containing 'appropriate warnings'.[21]

Long was convinced that curriculum development even at sixth form level should be in the hands of schoolteachers, and that only they had sufficient day to day understanding of what it was possible to teach youngsters. He wanted to try the material in schools, make appropriate revisions and demonstrate what was possible, before exposing what was at the time an incomplete course to the criticisms of subject specialists. Later, when he was faced with the possibility of having university physicists on the team, he could only accept it on condition that "....the schoolmasters' voice remained dominant".[22]

For the time being, Long had to accept the idea of an advisory panel of university physicists. He remained cautious, however, promising no more than to send them "....parcels of work from time to time (but not everything to everybody)".[23] The consultants' criticisms would be studied closely but the final decision would have to be the Nuffield team's. The consultants were to have no power of veto: "If they decide that our work was unsatisfactory they could withdraw their support at any time."[24]

Whether Long thought that the group of consultants would ever meet as a committee is doubtful: certainly he saw little purpose in "....long and large meetings which eat up time and can very often waste it."[25] In a note replying to Maddox's original suggestion, he had pointed out that the projects already had a Consultative Committee. Wenham supported Long's stance: "I recall watching such meetings in the early days of the "O" level project when Mac [Donald McGill] was alive and how they depressed him beyond all reason. But, in the end, he knew he had to do what he himself felt was right."[26]

The NFSTP Co-ordinator and Long exchanged letters with suggestions for membership of the university liaison panel. Of importance to the immediate future of NAP Keohane made a particular point of suggesting Dr.Paul Black, Reader in Physics at the University of Birmingham. In a previous letter on this issue, Long had suggested that he would like to have Jon Ogborn of Worcester College of Education on the sub-committee. In the event, neither of these suggestions was taken up. It is interesting to note here, that in just over six months' time Paul Black and Jon Ogborn would themselves be the Joint Organisers of the NAP project .

Despite these difficulties, Long had successfully introduced NAP draft materials into preliminary trials schools. He organised a two-day meeting at St.Hilda's College in Oxford on 30 September and 1 October 1966, so that the trials schools' teachers could discuss the minutiae of the materials and also look at demonstrations of apparatus developed by Harrap and Foxcroft. The cost of staging this meeting was about £200, which covered accommodation and travel expenses for 30 people. As the NAP project developed, and the number of trial schools grew to about 70, the cost of meetings like this became significant. So much so, that the Nuffield Foundation made arrangements with the Local Authorities with whom the teachers were employed (in the case of Independent schools, the Headmaster of the school) for the Authority to be responsible for the cost of travel and accommodation. At the Oxford meeting it was announced that during the trial period special examination papers would be set and recognised by all the Examining Boards as part of their own

Certificates. Headmasters and County Education Officers were informed of this important development during November 1966.

Costs to the schools were on the whole met by the LEA's or the schools themselves. The NFSTP adopted the policy that where a piece of equipment was fully developed and would be of value to the physics department the school authorities would purchase it. But where the equipment was in the developmental stage for NAP the NFSTP would provide it. Long estimated that about £750 would be needed for each year of the course, to purchase equipment.

By the autumn of 1966 Long was in a position to plan a major expansion of the NAP project and consider continuous trials schools' evaluations of the whole course during the two year period 1967-1969. Long himself hoped to retire from full-time work in 1969, and he had alerted Keohane of the need for a successor to oversee the publication which was planned for the start of the 1970 academic year. The A-level Consultative Committee agreed to his suggestion and on 14 November 1966 Long wrote to Keohane requesting extra funds. Meanwhile, Keohane passed on this substantial request to Brian Young and suspected that "....it [the request] will have to go officially in front of the Trustees."[27] At the time, the Nuffield Trustees were aware that the three A-level physical science projects were in need of further support but were waiting for Keohane's detailed analysis of the NFSTP to be presented at their meeting in February 1967.

Undaunted, Long began his planning to use about twenty schools for the continuous trials in three groups centred around London, the Midlands and the North with an even mixture of Comprehensive, Girls', Direct Grant and Technical Bias Schools and Colleges: "We have to remember the schools that have been taking part in the preliminary trials, and also those which will have completed the Nuffield 'O' course [NOP] and may be wanting to go forward into the 'A' course [NAP]. This immediately gives us too many schools, even if we ignore other claims, and I have a strong reserve list."[28] Long received many enthusiastic replies from the selected schools especially those involved directly in NOP, such as the Grammar School, Batley:

> "By July [1967] we shall have done three full years of this type of work, and both I [the Headmaster] and the members of the Physics Department have been most encouraged and delighted with the experiment....I can say without any reservation that we should be delighted to continue the work through to the A-level stage."[29]

Some Girls' Schools, however, were not able to help because none of the girls opted to study A-level Physics for the period of the trials:

> "Enquiry among the girls has shown that the most academic group, including several who have opted for Pure Mathematics, propose to keep to the Arts side."[30]

Whatever the outcome of his enquiries, Long felt that the geographical groupings were necessary so that 'group meetings' could be conducted on a regular basis. For this reason he initially omitted a number of schools in Bristol, Hampshire, Durham and Liverpool, on the grounds of remoteness, and he did not consider schools that were Secondary Modern. Long alerted his team members to the 'awkward situations' that might arise from his selection: "We are bound to displease some people, so perhaps we must not show our hand until we have counted the cards carefully."[31]

Certainly, towards the end of 1966 it was becoming apparent that Dick Long was 'playing his hand very close to his chest' and that, generally, there was a lack of public information about the NAP project and growing disquiet within the NFSTP itself. In particular, members of Mott's Joint Physical Sciences Consultative Committee were becoming concerned about the construction of Long's NAP course and its proposed exposure in extended school trials. Accordingly, Mott and Keohane decided to call a special NFSTP meeting at Chelsea College on 5 December 1966 to discuss the physics project. Three major criticisms were raised:

1. The NAP course was aimed at too diverse a group of students.
2. That 'teaching for understanding' is too time consuming and a more linear treatment, as attempted in NAC and NAPS, would be more successful. It would be unwise to single out physics for a completely different approach.
3. The NAP course was too wide and too general, including topics such as relativity, electromagnetism and quantum mechanics which the majority of pupils could not be expected to understand.[32]

Some university representatives felt that Long was trying to construct the NAP course along the lines presented in his contribution to the Schools Council Working Paper No.4 Science in the Sixth Form, where he emphasised the need for breadth and depth studies for a rapidly changing sixth form.[33] Long's defence of these criticisms was expressed in a circulated letter to his team members and, apparently, was not aired at the meeting itself. Long was not prepared publicly to defend his course; he wanted to suspend judgement until after the reports from the school trials. Wenham was more forthright: "It is exactly because the current linear and pedestrian courses have failed to attract enough of the bright young men and women to the sciences in the Sixth [Form] that we have been asked to undertake this work."[34]

More damning and painful criticism was felt at a NFSTP-SCUE Liaison Committee meeting. The newly formed Liaison Committee, between the Nuffield Foundation and a sub-committee of SCUE, chaired by Professor Jack Allanson, met in London on 25 January 1967, to discuss the progress and the subject matter of the three physical science projects, and, in particular, the physics project: "You [Keohane] will be aware that at its meeting in the summer the Standing Conference [SCUE] expressed the opinion that Universities had not received enough information about the Physics [NAP] course to enable them to come to conclusions on a reasoned basis....I believe that it is most urgent that some daylight be let into the workings of the Physics group."[35]

The Liaison Committee welcomed the Nuffield A-level experiment and were satisfied with the syllabus proposals and course development in NAC and NAPS, and only minor misgivings were aired. But despite Long's attempt to demonstrate the carefully constructed links in the NAP materials (see Figure 1), this project was attacked by the university representatives: "In discussion, criticisms were expressed both of the content and the length of the proposed course, which was considered to be too broad in its scope. Difficult topics were treated too superficially and doubts were expressed on the ability of teachers to conduct the course and of pupils to cover it in the time available. It was not considered suitable, in its present form, for preparation for university."[36]

In particular, Professors Allanson and Chambers considered the NAP conceptualization to be full of 'generalisations and pious hopes' and that the course itself was far too long for 5 terms of study. Professor Elton indicated that the presentation of the NAP syllabus was poor when compared to the clarity of the other A-level projects.[37] There was little sympathy for Dick Long's attempt to explain the unified structure of his NAP course.

Long's reaction to this meeting was swift. Within three days he had stated that "....in the interests of the project, I must be replaced as Organiser, as soon as the Foundation can arrange it."[38] He was clearly upset by what he saw as fundamental objections to the proposed course, and by the reluctance to allow the team to try out its ideas in schools before modification:

> "My stand is made entirely on the issue of the project's plans to introduce an introduction to the major theories [in Physics]. If the Foundation were in a position to give me a vote of confidence on this I would go on with the job."[39]

Dick Long sent his resignation to Brian Young and Kevin Keohane. Keohane suggested that Long should discuss his position with Professor Mott before any further action was taken, and conscious of the contrast with the welcome given to the A-level courses proposed for Chemistry, Physical Sciences and Biology, the Foundation began to seek ways of recovering the lost ground. A meeting was hurriedly arranged between the NAP project team and representatives of the SCUE Committee for 14 February 1967.

Meanwhile, there was a vigorous discussion carried on by correspondence among the team and between them and the Foundation.[40] Many of the team members were clearly shocked and surprised by Dick Long's resignation letter:

Bryan Chapman: " Todays letter from Dick Long has come as a considerable shock. One has the immediate personal reaction that the universities have rejected any experimental work on curriculum development that impinges directly on their work. If this is so then there clearly is no point in the Foundation expending effort on A-level projects....It is vital that this project succeeds as a university schools collaboration. But it is primarily the responsibility of schoolmasters and schoolmistresses! - to be judges of its suitability. It would be fatal if A-level was, or appeared to be, merely a preparation for university entrance. A study of Physics has something more to offer at any level."

Geoffrey Foxcroft: "I received a copy of Dick's letter this morning and feel numbed by the shock....I have great sympathy with Dick's views of what we should be trying to do in the sixth form and I feel compelled to say that, should Dick's resignation be accepted for the reasons put forward in his letter, then I should want to resign from the team as well."

Roger Harrison: "There is a matter of principle at stake here, which is that the Universities should not seek to dictate the content of school courses any more than outside bodies should dictate to the Universities....I very much doubt, however, that this is the real problem.Most academics I have talked to are content to grant the schools freedom of action. I think that it is much more likely that there has simply been a complete and disastrous failure of communication and that your [Keohane's] first efforts should be to remedy this."

Michael Smith: "It is only fair to point out that my confidence has been shaken by what has happened, and by the way in which the affair has been handled....Although I by no means agree with all of Dick's ideas, I could not have continued my association with him unless I had been in sympathy with the general philosophy behind his approach."
Bill Trotter: "I was so disgusted after our meeting at the Russell Hotel that I did not get round to saying to you [Chapman] what I felt should have been said. By this I mean that I appreciated your statement that 'anything good in what we had done up to that time could be credited to Dick'."

Ted Wenham subsequently resigned from the A-level project but not before he had persuaded the other NAP team members to remain. He felt it imperative to play down a 'dons-beaks' rift and that it would be wrong to abandon the idea of a physics project altogether.[41] Derek Harding, Keohane's assistant, was of the opposite opinion: "I think the A-level Physics Project was ill-conceived and I said so at the outset. I have said on numerous occasions that the appointment of Dick Long as an Organizer based in York was a mistake....The correct course for the Foundation is to state publicly that during 1966-67 a feasibility study was carried out....with the result that it was decided that nothing beyond the present A-level Physics syllabuses is required..."[42]

Throughout this, Long maintained that it was an issue of principle to be settled, while others saw it as a breakdown of communications to be repaired. Brian Young, the Director of the Nuffield Foundation, explained the juxtaposition of the two arguments to John Lewis: "Like you I am distressed about the events of the last fortnight; but I do not see this as just an issue between university and school people....I share your feeling that Dick Long is an extremely nice person, and I can well understand his commanding such loyalty. But the difficulty is that one does need to be a fighter, a thruster, and a communicator, to produce a first-rate Nuffield course..."[43]

Long's experience as an HMI had left him wary of the public statement and he had seen the value of avoiding premature exposure in the initial stages of the O-level work. The secrecy surrounding the NOP project protected the O-level Organizers, such as Lewis, from external pressures during the early developmental phase. The irony is that it was in his letter to Dick Long after the Loughborough conference in 1964 that Becher had made this very point: " ... we do not want detailed public criticism of them [NOP draft material] to be made before they have been tried out systematically..." (see reference **136** Chapter One). For Long, then, both issues merged as he tried to pursue the same policy. His NAP proposals should benefit from the same protection until the schools had shown what they could do and had had their say during trials. From this point of view, if he, the team and the schools were not afforded similar support in experimenting free of external influence to see if ‘the major theories’ could be introduced at this level, then the ground rules of Nuffield curriculum development had been changed. What he failed to see was that it was the ground that had changed. Not only had the O-level projects gone on to create now unavoidable public awareness of science curriculum development, more and more powerful bodies had a direct concern in any change to A-level. By the time that the A-level projects were starting, they were subject to the full glare of interested institutions, one of which was the Standing Conference on University Entrance (SCUE).

The meeting on 14 February 1967 between the remaining NAP team members, officers of the Nuffield Foundation and Professors Allanson, Chambers and Elton from SCUE was to prove decisive. The Chairman on this occasion was Sir Nevill Mott. For this meeting Professor Chambers, from the University of Bristol, had prepared a paper in order to present his criticism in a more systematic manner. The argument stressed that in his experience of first year physics students, schoolteachers tended to select parts of the A-level syllabus in a haphazard way. He supported his premise with the results of a survey he had just carried out with the help of 75 first year students. For example, 29% of the physics students had not done Faraday's law of induction at A-level, and despite this and other pruning, all his students had obtained at least a 'B' grade pass at A-level. Teachers saw pruning as the best strategy to maximise the students' A-level grade. Chambers argued that this attitude was likely to continue and would be disastrous in the NAP course because it was over-crowded and its structure made it difficult to prune.[44] He concluded "....that if the Nuffield course retains its present form, we in Bristol will feel it necessary to look very carefully at those who offer it as their entrance qualification in physics. I am sorry if this is regarded as "dictating to the schools". The universities have no wish to dictate to schools, but on the other hand, they have no wish to be dictated to by the schools. They would far rather co-operate with them."[45]

Other attacks focussed again on the style and presentation of the physics materials, when compared with the clarity of the chemistry and physical science materials. It was felt by the Nuffield Foundation administrators that the problem arose from the lack of communication between the university interests and the school interests. The development team reinforced this view, and they reminded those in attendance that the concept of a connected course, which emphasised understanding, was at the heart of the NAP proposals. Some hope of reconciliation was offered by Elton:

> "The programme of the Nuffield A-level Physics contains a lot of work which has not been taught before in schools. It doesn't mean these topics cannot be taught but university opinion is important....The team should be a joint university and school team."[46]

The university representatives from SCUE were not present at the second part of the meeting, where it was decided by Keohane, Mott and Young to accept Long's resignation in order to re-establish confidence all round. The Consultative Committee subsequently met on 20 February, almost one month after Long had formally submitted his resignation, and approved the action of the Chairman, Mott, in accepting it. It was felt that with more communication and discussion with the universities the 'advanced material' would eventually have been modified and would then have been acceptable to them. The committee requested that Mott inform Long of their deep appreciation: “In accepting your resignation, I am particularly asked to say, on a motion from Miss Kett and seconded by Allanson, how deeply we appreciate your work and how firmly we believe that a great deal of what you have done will be incorporated in the course as it finally emerges.” [47]

Long’s tenure came to a formal end on 26 February 1967 at a private meeting between Young and Long at Nuffield Lodge. They established an understanding of events that forced Long to resign, in order that suitable arrangements could be implemented by the Trustees to complete NAP. Long told Young that he did not feel able to start a new dialogue between schools and universities and, therefore, he supported the Foundation’s wish to initiate a new ‘one don and one beak’ leadership for NAP. When confirming the resignation and the understanding Young would write:

> “I am, as you know, very anxious that the phase 2 of ‘A’ level physics which will begin later this year should have a certain continuity with phase 1 for which you [Long] have been responsible; and that your resignation should not be taken to mean either that the Foundation lacks respect for you and for what you have achieved or that you lack confidence in what the Foundation is now doing to produce an ‘A’

level course acceptable to schools and universities alike. I therefore greatly welcome the understanding we reached the other day ... ."[48]

Even after a lapse of twenty years Ted Wenham regarded the events in the winter of 1966-67 as one of the most dreadful periods he had spent since World War II. His over-riding recollection was that Dick Long would not defend his strong case for the NAP course and suspects that it might have been the result of his many years working independently as an HMI.[49] Long was a highly respected , experienced HMI with strong personal qualities that invoked respect and loyalty from his team. As shown earlier , HMI in general were keen to involve less academic students in the NFSTP developments and Long was no exception: "In drafting the proposals[NAP], Dick Long had the needs of the less able pupils very much in mind."[50] In a similar vein he wanted to involve a wide range of schools in the continuing trials of the curriculum materials. Presciently, Long felt the need to broaden the A-level curriculum, a theme very much at the heart of the Nuffield Foundation's attack on A-level Science.

As McCulloch has been anxious to point out the NOP project, under Rogers' dominant leadership, took the view that "....competitive individualism and the motif of 'excellence' superseded the notion of leadership in school science initiatives..[and]..this vision was soon translated into an overriding aim for high academic standards."[51] Certainly, there is evidence that the university physicists on the various committees steering (not just consulting) the NFSTP physics projects were anxious to maintain A-level academic standards.

The resulting 'dons-beaks rift' highlights the sorts of pressures felt in A-level curriculum renewal and exposed some important weaknesses in Long's administration, particularly in the need to establish partnership and mutual respect between the schools and the universities. On this fundamental issue, Keohane felt that: "The team [NAP] as a whole is too lightweight. At A-level it is imperative to have more full-time and more university people actively associated."[52] At this time, January 1967, Keohane had just completed a major review of the NFSTP organisation and finances, and had concluded that all three physical science projects were too lightweight. Long, of course, had been working with restricted provision and secretarial help but, that said, even after 12 months he had not been able to produce and exhibit materials to a standard comparable with those in NAC and NAPS, at a comparable stage in their development.

For instance, at the beginning of 1967 Long's course still consisted of a large number of unedited papers, many still in hand written form.

Perhaps the period of administrative change at the Nuffield Foundation during 1966 helped to mask the problems emerging in the first phase NAP developments. As far as NFSTP administration was concerned, the reconstruction of NAP would hinge on the decisions of both the new Director, Brian Young, and the new Co-ordinator, Kevin Keohane, and they would be on hand to see the project through to completion. Further questions were asked about the composition of Mott's A-level Consultative Committee. It was felt that it was too heavily weighted towards university opinion and that it needed more school-teacher representation.

Finally, there was the thorny question of the school trials and how to explain the delay in producing A-level physics materials. Keohane and Long eventually agreed on the format for a letter that did not suggest to the schools a complete division between them and the universities. This would only prejudice the 'ultimate successful completion' of the physics project:

> "The proposals for the Nuffield A-level Physics Course have not yet reached a stage where they can be considered acceptable to the Foundation for trials in schools. It would be clearly unwise to rush matters at this stage and it seems advisable not to continue with the preliminary trials in this school year or with the introduction of continuous trials from September 1967. It is hoped that trials will begin in 1968 and your offer of co-operation will not be forgotten. The arrangements we have made with the Examining Boards for 1968 to cover the variations in courses you have already undertaken still hold. Please let me [Long] know if you think this change of plan will prejudice the chances of your pupils."[53]

The success of the NOP project in some schools and the enthusiasm for schools to accept Long's offer of trials status would provide an important resource for the second phase NAP developments.

In exploring the 'historical underpinnings' that led to the upheaval in the NAP project a number of 'unlearned lessons' has emerged. It is clear that the conflict between the NAP Organizer and university physicists revolved around two key issues: first, the nature of the proposed physics course; second, the character and organizational ability of Dick Long. The physics scheme, proposed by Long and his team, tackled not only the need to modernize the content of A-level Physics courses but also carried forward the change of teaching methods in schools begun by NOP. Such an approach was consistent with the developments in PSSC and in NOP; therefore the new NAP course was very much 'of its time'.

At the time, A-level Physics syllabuses were still constructed along the lines of the Gulbenkian inquiry and topics were arranged under traditional headings of: General Physics (or Mechanics, Hydrostatics and Properties of Matter), Heat, Light, Sound, Magnetism and Electricity.[54] The NAP scheme sought instead to emphasise the basic principles and structure of Physics and sought themes to link the topics together, as can be seen in the papers extant at the time of Long's resignation and in Figure 1 (page 60).

In choosing possible 'end-points', and unifying concepts, based on Quantum Theory, Relativity and Thermodynamics, the NAP team was trying to construct, and then test in school trials, a coherent course which fully developed students' ideas and conceptualization in Physics. The idea of choosing these 'advanced end-points' was not to usurp university physics nor to prepare all students directly for Physics degrees. In following the lead set by NOP, the NAP team also hoped to develop a 'growing acquaintance' with the concepts so that the idea of a step-by-step, linear course was not considered. In this, the NAP apparently differed from the other Nuffield A-level proposals and the 'linearity' argument was picked up by the universities. Perhaps the university physicists felt a strong need for a linear progression in Physics based on the structure of their own courses within the universities, although it is difficult to see how Heat, Light etc. are organized into university physics involving, for example, Wave Equations, and Quantum and Statistical Physics. Inevitably, in Physics, the ideas and content get driven downwards into the schools, partly as a result of new theories being formed and partly because school teachers, who have been trained in university physics departments, want to pass on their knowledge to their pupils. This may have helped create the impression that a linear progression was necessary.

Also, it is apparent that the university physicists were more concerned with the content of Long's course rather than with the methods of teaching the chosen physics. As a result of the Nuffield O-level developments there had been a considerable change in some teachers' approach in the laboratory, and teachers were used to being involved in curriculum development activities. It seems as though the ideas behind the NFSTP, particularly NOP, had not yet impinged upon the universities, and that they were not fully aware of the extent of the changes taking place in schools. Nor did they comply with Long's strongly held view that sixth-form curriculum development, particularly when it heavily involves changes to teaching styles, should rightly be in the hands of experienced practitioners, the school teachers.

NUFFIELD A-LEVEL PHYSICS: INDEX OF PAPERS (September 1966)

		Title	Author
Conversion Course			
P0	.1	Sketch of half-term course	E.J.Wenham
	.2	Conversion Course	E.J.Wenham
Materials			
P1	.1	A-level Teachers' Guide	D.W.Harding
	.2	First stage	H.J.W.
	.3	Teachers' Guide	R.D.Harrison
	.4	Another draft	V.J.Long
	.4(a)	Schlieren Ripple Tank	M.J.Harrap
	.4(b)	3cm model x-ray Crystallography	M.J.Harrap
Electricity			
P2	.1	First draft	V.J.Long
	.2	New version	V.J.Long
	.2(a)	Hall coefficient in Aluminium	M.J.Harrap
	.3	Introductory Treatment of Circuits	B.R.Chapman
Dynamics			
P3	.1	Dynamics	V.J.Long
	.1(a)	Other items to be given a place	V.J.Long
	.1(b)	Further points about energy	V.J.Long
	.1(c)	Trolley Kinetic Energy	J.R.Stewart
	.1(d)	Sphere proof	M.S.Smith
	.1(e)	Kinetic Theory formula	G.E.Foxcroft
	.1(f)	Kinetic Theory formula	A.W.Trotter
	.1(g)	Kinetic Theory formula	M.J.Harrap
	3.2(a)	Dynamics	E.J.Wenham
	.2(b)	Some experiments	E.J.Wenham
	. 2(c)	Rotation	E.J.Wenham
	3.3	Rotational Motion	B.R.Chapman
	3.4	Forced Vibrations and Resonance	A.W.Trotter
Fields			
P4	.1	Electrostatic Fields	V.J.Long
	.2	Uniform Fields Electrostatics	J.M.Ogborn
	.3	Electrostatics a possible approach	G.W.Dorling
	.4	Worcester Papers on Electromagnetism	E.J.Wenham
	.5	Electromagnetism	G.E.Foxcroft
	.6	Approach to Electromagnetism	B.R.Chapman
	.7	Radiation detection by ionization in gases	R.D.Harrison
Atomic Structure			
P5	.1	Energy levels to Periodic Table	J.M.Ogborn
	.2	Atomic Structure and Interatomic Forces	F.R.McKim
	.3	Atomic structure	V.J.Long
	.4	Atomic Structure	B.R.Chapman

Oscillations			
P6	.1	Harmonic Oscillator	J.M.Ogborn
	.2	Suggestions for inclusion (sound)	D.Longhurst
	.3	Oscillations and waves	A.W.Trotter
Alternating Circuits			
P7	.1	Alternating Currents and Voltages	G.E.Foxcroft
	.1(a)	Experimental Appendix	G.E.Foxcroft
Electronics			
P8	.1	Electronics	D.J.Read
	.2	Electronics	G.E.Foxcroft
	.3	Digital Techniques	R.J.Long
Quanta			
P9	.1	(see 5.1)	
Waves and Physical Optics			
P10	.1	Physical Optics	G.E.Foxcroft
	.1(a)	Polarization	G.E.Foxcroft
	.2	Waves	V.J.Long
Electromagnetic Waves			
P11	.1	Chapters X,Y,Z	G.E.Foxcroft
	.1(a)	Appendix to Electromagnetic Waves	G.E.Foxcroft .
	2	Electromagnetic Radiation	B.R.Chapman
Relativity			
P12	.1	Approach to Relativity	R.G.Harrison
	.2	Modified Bondi	M.S.Smith
	.3	Errors of Observation	G.E.Foxcroft
Thermodynamics			
P13	.1	Thermodynamics and Boltzmann	V.J.Long
	.1(a)	Note to be given a place	V.J.Long
	.1(b)	Supplementary note	V.J.Long
	.2	Energy Distribution	G.E.Foxcroft
	.3	Temperature and Thermometry	G.E.Foxcroft
Spectra and Quanta			
P14	.1	(see 5.1)	
Wave - Particle Duality			
P15	.1	Energy levels to Periodic Table,2	J.M.Ogborn
	.2	Some Thoughts on Wave Mechanics	M.S.Smith
	.3	Electrons in Metals	V.J.Long [55]

Long, of course, had been actively involved in modernizing the content of the O-level Physics syllabuses and in the NOP developments, particularly with examination arrangements and in disseminating the ideas into schools. It was natural, then, for Long to propose a radical course in much the same way as McGill and Rogers had done for O-level. Interestingly, Long's NAP proposals were considered by the universities as much more revolutionary than the integrated physical science suggested in NAPS, and were subjected by them to much greater criticism. The universities at that time were prepared to contemplate a combined physics and chemistry A-level, with its implied reduced physics content, but they could not condone radical changes to an establish academic subject, Physics.

University pressure, combined with a late start, poor levels of funding, Long's isolation in York and an incomplete course not yet tested in schools, created an impossible situation for the NFSTP. The problem was exacerbated by Long's inability to communicate the basis of his ideas. In public, he was not a 'fighter' nor a 'thruster', preferring instead to keep his ideas very much within the NAP team and his hand close to his chest. When faced with a confrontation, it could be said that in resigning, Long backed down and simply aided those people he wished to oppose, and perhaps this reaction to criticism was as a result of Long's many years working within the independence of Her Majesty's Inspectorate. Moreover, he had passed retirement age and even in accepting the job had mentioned that he might not wish to stay on until the end.

But, the most telling line in his letter of resignation is “If the Foundation were in a position to give me a vote of confidence on this [the plan’s to introduce an introduction to the major theories of physics] I would go on with the job”. While unprepared to fight things out in public, Long did not simply quit. He took a stand. He confronted the Foundation with a choice - back me over the approach, or I go. How strong he thought his position to be is hard to guage. His resignation generated considerable shock in the NAP team, who were fiercely loyal to Long's proposals and to Long himself. The NAP team, however, were mostly on a part-time footing and were widely scattered and, as such, could not provide a power base to counter the criticisms.

Later events were to prove him right in that the final NAP published scheme contained just those major theories over which he took his stand and their teaching at A-level was accepted by the universities. What is more, at the very meeting of the Consultative Committee which approved the acceptance of his resignation, it was noted that this was likely to happen. For the Foundation, therefore, this was not the crucial issue; what mattered was Long’s intransigence over consulting the university interest at this stage of the development. Certainly Long's refusal to engage in adequate communications, especially with the universities, focussed the pressure. Yet Long did not feel that this was a problem:

> "We have to patch up the enterprise in a way best calculated to maintain the support on one side [the schools] and regain it on the other [the universities], and for this reason the recent lamentable confrontation must be played down. At the same time, I am not prepared to confess to sins when I don't feel guilty. I am retiring

because university physicists object to our general proposals....not because I have been remiss in consulting and communicating, which is a point made at the meeting you [Mott] had with the team, as reported in the minutes now circulated....Had university physicists been asked for advice at the outset the schoolmasters would have tended to defer, and the needs of the subject could have overshadowed the needs of the pupil."[56]

Clearly, Long was remiss in consulting and communicating. It is interesting to speculate that if Long had been given more time, greater levels of funding and been left alone until he had developed a complete and tested course, he would have been able to put over his ideas for NAP more forcefully. Perhaps Long's appointment was not simply a case of the wrong person for the job. Any person put in the situation of proposing a radical course at A-level would almost certainly have been exposed to criticism such as those levelled at Long and at some time would have had to be a forceful communicator. His important failure was that he was unable to identify the problem at the appropriate time. Others did, however, and his resignation was accepted

Faced with the hostility and an overall lack of support from the NFSTP Long must have felt an awful sense of failure after such a distinguished career as an HMI. As such conflicting impulses coincide, it is worth noting Paul Black's words:

> "The variety and intensity of the efforts to innovate does not guarantee their successes, but it does at least suggest that valuable lessons may be learnt by detailed study of their failures. It is an old trap to imagine that new ventures will not suffer from the old constraints."[57]

The NFSTP, and physics education in general, undoubtedly owes a considerable debt to Long for his prescience of what it is possible to teach at A-level, his willingness to experiment with teaching methods at this level and his courage to emphasise the schools' needs in post-16 curriculum development. In the short term, Long's failure contained many valuable lessons for the resurrection of the Nuffield A-level Physics programme. In a wider sense, the 'unlearned lessons' from Long's failure should help future post-16 curriculum development to create more long-term successes like the Nuffield A-level Physics project.

CHAPTER THREE
The Don and The Beak - revitalising Nuffield A-level Physics

During the Autumn of 1966 and the Spring of 1967, Professor Kevin Keohane [1], newly appointed Co-ordinator of the NFSTP and, later, Chairman of the Governors of the Nuffield-Chelsea Curriculum Trust (NCCT), worked quickly to re-establish the credibility of the three A-level physical science projects and strengthen relationships with the Examining Boards and the universities. He organized a complete review of the Foundation's allocation of NFSTP financial resources and he outlined long-term proposals to help the Trustees carry out their wish to disengage from responsibility for the NFSTP: Keohane and the Trustees hoped to institutionalise the projects within a university. In short, Keohane set in motion plans that led to the successful publication of the A-level projects and the implementation and after-care for all the science projects.

Earlier in 1966, John Maddox had decided to relinquish his post as Co-ordinator and become Editor of the science journal *Nature*. At this time Maddox had been approached by Dr.Malcolm Gavin, Principal of Chelsea College of Science and Technology [2], to help set up a science education unit within this institution. [3] Maddox used this contact to suggest that Kevin Keohane would be a suitable successor: "One man who might do is the professor of physics at Chelsea - Keohane. I suspect that Gavin would find it relatively easy to get the academic teaching done and that he would welcome an arrangement creating some kind of link between the Science Teaching Project [NFSTP] and his own institution."[4] Maddox, of course, was extending Tony Becher's initial idea that the NFSTP be seen as an independent organisation based separately from Nuffield Lodge. In the future, September 1979, The Nuffield Trustees would hand over total supervision of expenditure to a carefully constituted body, the Nuffield-Chelsea Curriculum Trust, devoted to science education and curriculum renewal, and based at Chelsea College:

> "....if we [the Nuffield Foundation] try and exercise control then we have to be seen to have the backing of the Trustees, but the Trustees do not like to be bothered with detail in this connection

[expenditure] because of the complications. It is for that reason that they have opted for handing over to Chelsea, because in that way they hope to avoid having to be concerned with supervision."[5]

As a first step in this direction the Trustees appointed Kevin Keohane as Co-ordinator on 6 May 1966 with the idea 'very much in the Trustees' minds' that Chelsea College would absorb the administration of the NFSTP by the autumn of 1967. They also recorded the longer term view, that the Trustees: "....would be prepared to offer the copyright of the Nuffield Science Project publications to the Chelsea Centre, on the understanding that the Centre would assume continuing responsibility for keeping the materials up to date, and would provide some means of ensuring that the income from sales was devoted to appropriate non-profit making academic purposes."[6] In time, the other Nuffield Foundation teaching projects would also be administratively centred within university departments.[7] During this period of reorganization the Trustees had been alerted to the explosion of curriculum projects in the United States. Brian Young's visit during 1965 had uncovered many 'hollow projects' to serve as a warning to the Trustees: "....there seemed in places to be a woolly hope that "togetherness" would be enough; provided teachers from university and school talked long enough with each other, it was hoped that something would emerge."[8] At their meeting on 17 February 1967 the Trustees felt that in any future allocations to education, they would wish to consider fields other than school curriculum projects. This policy continued for most of the 1970s and 1980s. For example, in 1984 Professor Keohane wrote to Lord Flowers, a Nuffield Foundation Trustee, to explore the possibility of financing assistance to develop new curriculum materials at 16+ in anticipation of the wholesale movement towards the GCSE examination. In his reply, Lord Flowers reiterated that: "....the Nuffield-Chelsea Curriculum Trust was intended to be self-financing and that the Trustees would be unlikely to make a grant for the revision of the existing courses....they would only consider a proposal that was entirely new and at the same time close to their current range of interests."[9]

However, for their meeting in February 1967 the Trustees had asked Professor Keohane to prepare a detailed analysis of the NFSTP, including his plans to reconstruct the A-level projects, particularly NAP, and his proposals to complete the existing science projects at Chelsea College.[10] As mentioned previously, the Trustees, after much discussion, agreed to increase their financial commitment by about £233,000[11] to meet the demands of the A-level physical science projects and the follow-up costs of the other science projects. In effect, Keohane and the Nuffield Foundation officers were given a mandate to:

1. reconstruct NAP from scratch,
2. rejuvenate NAC and NAPS, and complete NAB,
3. strengthen coordination between the NFSTP, the universities and SCUE,
4. strengthen the continuation programme for the recently completed O-level projects,
5. complete and provide 'after-care' for the Junior Science, Secondary Science and Combined Science projects,
6. partly finance and negotiate A-level examination procedures with the Examining Boards and with the Schools Council,

and 7. continue to investigate ways in which the Foundation could disengage responsibility from the NFSTP, use its income from curriculum publications and accommodate its concern that curriculum renewal should become a continuing process.[12]

Fortified by this vote of confidence, Keohane and Young immediately began the task of stabilizing the A-level physics project. Ted Wenham, despite his decision to resign from the A-level team, exerted his will on the other team members, requesting their continued support and experience to assist Long's successor.[13] Young, in particular, wished to appoint a joint management team, of one university-based teacher and one school-based teacher, to plan a course capable of commending itself to both the universities and the schools. He was keen to synthesize the disparate positions by means of "....a vigorous and early exchange of views between dons [university teachers] and beaks [school teachers], which will meet the reasonable points made from the university side without sacrificing the interest and value for sixth-forms of the pupil-centred approach that is characteristic of Nuffield Science."[14]

In organising this move, Young had invited Keohane and Wenham to Nuffield Lodge to discuss the future of the second phase NAP and use Wenham's polymathic knowledge about the Nuffield physics programmes. It was agreed that there should be Joint Organizers and Wenham suggested that his recent appointment at Worcester College of Education, Jon Ogborn,[15] would be an excellent candidate for the 'school teacher' side in the partnership. Lately, Ogborn had taught physics at Roan School in Blackheath, London, and had been appointed to Worcester to start up courses for serving teachers based on NOP materials. He had been involved in the A-level work, writing several papers, including one about Wave-Particle Duality and the graphical solution of the Schrödinger Equation, and in developing equipment to teach electromagnetism. Furthermore, John Lewis had invited Ogborn to join the ASE Apparatus Committee so he was familiar with all the equipment being developed for the Nuffield physics projects.[16]

Keohane's choice for the university teacher side was Paul Black, and this coincided with Wenham's view. At the time, Paul Black was an academically respected Reader in Crystal Physics at Birmingham University who had replaced Keohane as Secretary to the Education Group of the Institute of Physics. Black acknowledges that he became a university lecturer because he had an interest in teaching as well as research.[17] His ideas on university physics teaching were focussed during an IPPS enquiry, conducted during the early 1960s into assessment methods used in physics degrees.[18] At the same time he conducted trials of new 'group-study' courses in the Department of Physics, involving "....a variety of informal discussions in groups or sub-groups, student lectures, written essays, individual and group attempts at problems and laboratory investigations . Formal lectures by staff members played only a small part in the teaching process."[19] It is a feature of the NFSTP that many such ideas initiated by university personnel were successfully integrated into projects like NAP and later were to spread their influence beyond A-level to O-level and eventually GCSE .

This enthusiasm for teaching had encouraged Paul Black to extend his involvement with school physics and he became an A-level examiner for the JMB. He was eventually appointed as one of the four university members to the Joint Matriculation Board with special concern for its Subject Committee for Physics. Through personal contacts and his proximity to school physics teaching, Black was aware, in vague terms, of the situation in Long's A-level project and he felt concerned about the developments.[20] Therefore, Black readily accepted Keohane's invitation to discuss the possibility of organizing a second phase NAP project. By 23 February 1967 Keohane had met both Paul Black and Jon Ogborn and had outlined the necessary commitment and the Foundation's wish to have part of the project based in London: "It is essential that we should retain close contact with other projects, for instance the biologists can teach us a tremendous amount about the ways in which they evaluate the courses during their progress through the schools and the way in which they classify feed-back from the schools."[21] Keohane also indicated that in the future one person would need to work in London in close collaboration with the editorial and publishing side of the project: "I [Keohane] have in mind that perhaps towards the end of 1968 Black would take a lesser part in the project, and perhaps at this stage, Ogborn might transfer to London to see the work through to publication."[22] In due course Ogborn accepted a post at Chelsea College and was able to fulfil Keohane's plans.

Months earlier Jon Ogborn had arranged for the Physics Department at Birmingham University to provide some lectures for the in-service teacher training courses at Worcester and he had worked with Paul Black to finalize topics and organization. Therefore Black and Ogborn agreed that they could work closely together on the Nuffield project and, initially, they used the Physics Department at Birmingham as the main administrative centre.

What, then, was left for the new NAP Joint Organizers to build upon? Firstly, the NFSTP had an employment responsibility to Trotter and Harrap and, due to Wenham's foresight, the basis of a team was still intact. In order to assemble an entirely new team with extended secondments would have caused even more delays and, anyway, many of the best physics teachers of the time were already on the team. After much discussion, the basic curriculum platform of Long's course was felt to be sound, and many of the ideas and teaching sequences would eventually find their way into the published NAP course.

Further discussions were held with Sir Nevill Mott and with Brian Young, so that by March 1967 it was possible to involve some members of Long's team in the negotiations. Bill Trotter, Martin Harrap and Geoffrey Foxcroft were invited to a meeting on 17 March, chaired by Mott, to discuss with Black and Ogborn the concepts and skills needed in an A-level course. There was a general consensus that NAP was 'going along the right lines'. At this meeting Black and Ogborn publicly committed themselves to act as Joint Organizers for phase two NAP.[23] A major factor in Black's decision was that he was being asked to construct a whole course which was a 'far more interesting job' than the syllabus revision exercise he had carried out for the JMB. He was relieved of his teaching and administrative duties at Birmingham and arranged to be seconded for three-fifths of his time. On the other hand, Ogborn was seconded full time from Worcester for two years.

The two men began their preliminary planning and organization work immediately even though their appointments to the Foundation were arranged in July, and work officially commenced in September 1967. The physics course was now potentially two years behind the other A-level projects, or, in Paul Black's eloquent words: "We needed to set ourselves a pretty fearful timetable."[24]

Black and Ogborn quickly realized that they had barely twelve months, Spring 1967 to Spring 1968, before they would need to hold briefing conferences for their first set of trials schools. By then a firm outline of the whole course was needed and teaching materials and equipment for the first year trials would have to be available. Black recollects that one of the worst constraints at this time was the extensive 'lead-time' needed for apparatus. It was necessary to decide on what equipment should be used, or developed, even before the course has been constructed: "....it may be a decision taken by a curriculum developer about how to produce an apparatus specification which must be ready next week because if it isn't the manufacturer won't have it ready in six months' time, and the school trials won't be able to start with it then, so they won't be finished in eighteen months' time, so the feedback won't be collected in two years' time, so the revised version can't be prepared for the publisher in two and a half years' time and the books won't appear in time for the schools to be able to embark on the course in four years' time."[25]

In any event, Black and Ogborn were soon inundated with the 'nuts and bolts' detail of this type of curriculum renewal. For a start, even before the period of preliminary planning, April to December 1967, Black and Ogborn were asked for an estimate of equipment costs to assist prospective trials schools. In line with the original estimate given by Dick Long, they suggested about £500 for each of the two A-level years. After a year's trials, however, there was a dramatic change in emphasis. An announcement in the July 1969 issue of Physics Education reported that NAP apparatus for the first year (16 students) was likely to cost £1000 and for the second year £500. These estimates indicate that the use of apparatus in experimental work is fundamental to the teaching and learning in the NAP course.

Overall, the second phase NAP curriculum developments involving the preparation and publication of the equipment and materials during December 1967 to Autumn 1972, are clearly illustrated elsewhere in generic publications written by the physics team members.[26] Of particular note, here, are John Ogborn's evocations in Physics Education: *Decisions in curriculum development - a personal view*.[27]

Jon Ogborn, on full-time secondment, travelled the 25 miles from Worcester to Birmingham most days of the week and the Joint Organizers worked very closely on their management task. Firstly, they had to decide, with Professor Keohane, the composition of their team and their working locations. They arrived at the following arrangements for the new team:

- The Joint Organizers based in the Physics Department of the University of Birmingham.
- Bill Trotter (full-time secondment) and Bob Fairbrother (almost full-time secondment) working together at Chelsea College, London.
- Geoffrey Foxcroft (two-thirds secondment) and Martin Harrap based in the science laboratories at Rugby School.

Discussions were held with all the first phase team members, and with Dick Long, to keep everyone fully informed of the changes.[28]

Secondly, there was an obligation to restore confidence in the Nuffield A-level physics project and "...to get the structure, philosophy and image back on course after a very bad time."[29] In particular the SCUE Liaison Committee and the Nuffield Physical Sciences Consultative Committee loomed large on the Joint Organizers' horizon as important groups to satisfy. No less important was the task to restore confidence in their team members: many of them had been demoralised by events and Paul Black acknowledges their character in that they agreed to continue to work for the new management team. Finally, there was the need to produce plans for the new project as a whole and circulate full specifications to the universities so that any feedback could be considered in the writing of the first draft materials.[30]

In implementing these affairs Black and Ogborn had the distinct advantages of hindsight and cooperation, despite their extremely tight timetable. In the two years since the start of NAB in 1965 and the Autumn of 1967, when the physics team effectively began full-time work, the idea of centralized curriculum development had become institutionalised within the Nuffield Foundation and at the Schools Council, where a plethora of 'daughter projects' was being considered.[31] The Examinations Boards were now fully involved with large numbers of Nuffield O-level students, and A-level trials students in NAB and NAC, being tested in novel ways and using the untraditional curriculum materials. Besides this, the traditionally impenetrable university departments were by now aware of the groundswell of change in schools. Moreover, in March 1967, Black and Ogborn had been involved in detailed discussions with NFSTP physicists about the nature of an NAP course and what ideas could be salvaged from the first phase developments. At this time, they were advised by Keohane that the Trustees had allocated further funds to restart NAP virtually from scratch. Consequently, Black and Ogborn planned to commence the second phase NAP with a clean slate:

> "We did make a fresh start. We were told, and we decided, that we would start again. So we began by thinking about the nature of the whole course from the beginning, not just taking over what was already there. Although what was there [of Long's proposals] was substantially used."[32]

After all, the collection of papers about content and teaching strategy which Long had bequeathed them (albeit handwritten and unedited) did include four written by Ogborn particularly his influential contribution to the key 'end-point' topic of energy level in atoms incorporating wave-particle duality. So even though Black and Ogborn did not set out directly to extend the course Long planned, they were still planning to use some features of the first phase and, of course, these ideas were still open to the same criticisms, as from the outset, Dick Long and his team had been determined to use the opportunity for radical change:

> "If it [NAP] is to serve a useful purpose the A-level project must have a distinct probability that it will fail. If we try something so conservative that it is bound to work, very little advance on the present situation will be achieved. I [Roger Harrison] hope the Foundation, and the universities, are prepared to recognize and accept this risk."[33]

In adopting Long's general curriculum platform, Black and Ogborn also felt that the opportunity provided by the Nuffield Foundation was a substantial one and unlikely to be repeated and "....it seemed right to think from the outset in terms of a radically new course rather than in terms of modifying existing syllabuses."[34] The essence of the university criticism centred on the question: why should the course contain watered-down advanced physics, such as wave-particle duality, statistical thermodynamics and relativity, when the basic physics should be done more thoroughly?[35] Of course, there was considerable debate among the interested university teachers. Professor Chambers had argued earlier that: "These are all sophisticated and intellectually demanding concepts, and in most universities they are not seriously tackled until the second and third years; the first year is spent in laying the foundation for them."[36]

Alternatively, Professor Charles Taylor, from University College, Cardiff, thought "....it is a good thing that new topics had been introduced into the curriculum at A-level. Things met at school were not so frightening when dealt with at university."[37]

Using retrospection, Black and Ogborn put considerable efforts into consultation and careful presentation of their ideas, distilled into policy papers P-GEN 1 to 5. [38] To their advantage vocal critics of Long's course, in particular Chambers and Allanson, could not continue to be obstructive and 'knock-down' the new management team.[39] Now, in accord with the other Nuffield A-level projects, Black and Ogborn announced in P-GEN 1 that they had set up working parties of university teachers and school teachers:

1. Electric and Magnetic Fields and Electromagnetic Waves: Professor Allanson and Dr.Whitworth (Birmingham University), E.S.Shire (King's College, Cambridge) and W.K.Mace (King Edward VII School, Sheffield).
2. The teaching of the physics of solids: Professor Chambers (Bristol University), Dr.Bailey (Morgan Crucible Company), Dr.Kelly (National Physical Laboratory), Professor Pratt (Imperial College) and four team members.[40]

It is clear, therefore, that Black and Ogborn were carefully prepared for their first vital meetings with the Joint Physical Sciences Consultative Committee and with the SCUE Liaison Committee. As early as May 1967 they presented their first paper *Statement of Aims* to elicit views from Consultative Committee members, most of whom were closely involved in the NAC and NAPS projects. [41] These aims were then forged into the outline of a course which was discussed at the next meeting in December 1967.

In the meantime, on 27 September 1967, a carefully worded 33-page document was presented to the previously intimidating SCUE Liaison Committee. The first pages indicated that only about 8% of those people taking A-level physics, in 1965, went on to study physics at university and so it would be wrong to produce a course just for the academic elite who go on to a physics Honours degree.[42] The meeting agreed that a similar document be sent to all interested university departments and P-GEN-4 was distributed in November 1967. The document clearly reinforced the point that the views of university physicists, or engineers, about what physics is included and how it should be taught can carry substantial weight, but only if there is agreement between university departments and the educational interests: "It frequently happens that the possibility of teaching a topic at this level [A-level] depends upon the exploration of new and simple ways of explaining the problems involved and on the development of experiments which will present these problems in a concrete form to arouse discussion. It is often not possible to decide whether or not a subject can be taught until various ways of treating it have been explored."[43] On reflection, Paul Black remembers that some, though not all, of the contributions from the SCUE committee were helpful and that some members readily provided help on an informal basis.[44] So at the end of a turbulent year for the Nuffield A-level physics project the Joint Organizers were able to look forward optimistically to 1968 and the exploration of their ideas for the coursework.

Both Black and Ogborn were convinced that the NAP course should have a pattern and 'tell a connected story' and that every bit of physics selected should 'earn its keep' and tie in with other parts of the course: "Learning is helped if ideas studied in one section are taken up and used in later work, and it is an important and valuable characteristic of physics that ideas.....do come together and interact fruitfully when quite different problems arise."[45] Such coherence can be achieved by establishing an end-point (or end-points) which can serve as a way to bring together and interrelate the physics done in several areas. Eric Rogers used this curriculum technique when devising his 'Block and Gap Scheme' at Princeton University, which is described in *Teaching Physics for the Inquiring Mind* : "There is my course outline, written *backwards* - a healthy way to write any syllabus."[46] In much the same way, Rogers had influenced both PSSC and NOP courses, and their evolution from carefully argued end-points. Jon Ogborn, in particular, was heavily influenced by Rogers' ideas at this time and Rogers "....was something of a hero, with good reason."[47]

It was soon recognized by the Organizers that three major theories reflected in the shape and structure of the physics they were looking for:

1. The nature of electromagnetic waves.
2. The Second Law of Thermodynamics from a statistical point of view.
3. The ideas of quantum physics and wave-particle duality.

Although not reacting directly to Long's course, Black and Ogborn were helped by the fact that a great deal of time had already been spent in developing these areas. Long emphasized in his 'resignation document' their importance, in his view, to NAP:

> "The work that seems essential on the laws of thermodynamics, the nature of electromagnetic radiation and then the quantum-mechanical view I have reduced to a minimum and now believe it can be confined within a single term. Even if these cannot be examined, and I don't accept the suggestion, the ideas are too germane to ignore."[48]

There were abundant arguments for and against these proposed end-points. For example, one of the continuing team members, Martin Harrap, wrote to Black strongly supporting 'electromagnetic waves' as a major end-point: "A sensible school treatment must start with experimental evidence that electromagnetic waves exist, and then attempt to relate them to electric and magnetic fields....A lot of applied physics can come in, and the applications are often familiar."[49]

After a number of meetings and discussions with both the Consultative Committee and Liaison Committee, it was finally decided in December 1967 to opt for end-point '3': "A study of waves and particles and atomic structure will be the end-point of the course: this demands, links together and uses work on waves (interference, wave equation, standing waves) and on atomic structure (electrons, Rutherford model, empirical evidence on atom sizes and energy levels) together with some electrostatics, dynamics, optics and ideas of statistical behaviour."[50] This strategy did not emphasize the nature of fields and radiation. So, in order to restore the balance, a main study of electromagnetic waves was planned, together with brief treatments of exemplary problems in relativity and thermodynamics.

Ogborn's personal reflections explain how very gradually during 1967 and 1968 the NAP Organizers developed these ideas and came to see physics as structured in three broad strands: thinking about the idea of a field; moving between macroscopic behaviour and microscopic explanations explains what matter is like and, finally, analysing motion and change. [51] (The three columns in Figure 2 depict these areas of the selected physics. Figure 2 also illustrates the links to the remainder of the course which develop from, and are implied by, the chosen end-point.)

John Lewis, who described himself as just an NAP trials teacher, uses these connections, and the implied unity of physics, to support the principles behind the Nuffield physics courses:

> "In Unit 10, the student needs the ideas of crystal structure studied in Unit 1, a knowledge of electrons and energy levels from Unit 2, the concepts of field and potential from Unit 3, the ideas of waves and in

particular standing waves from Unit 4, the Rutherford model of the atom from Unit 5, the concept of photons from Unit 8 and statistical ideas from Unit 9. It is the best teaching I have encountered anywhere for showing the unity of the subject, for showing that physics as a whole makes sense."[52]

Because of the radical nature of some of the selected physics both the NAP teams spent much effort in finding novel ways to present these ideas, as well as the more traditional topics, to a broadly based sixth-form. The interaction of content selection and curriculum process meant that the Organizers had to look carefully at the main aims of the course, "....so that a topic is judged as a vehicle or example for developing understanding and skills which may be of more lasting value in the future than the acquaintance with a particular topic itself."[53] The set of general aims, including the intention to equip students to learn for the future, are offered in Chapter 3 in the NAP Teachers' handbook and are intended to imply practical objectives and skills which can be developed in the course and then, importantly, tested in an A-level examination profile.[54] (Table 2 lists these aims, with examples of the objectives they imply.)

A notable feature of many of the curriculum development projects mentioned in earlier chapters is the emphasis placed on the articulation of curriculum positions (e.g. statement of aims, commitment to understanding through an inquiry approach, adoption of a particular learning theory, etc). In the case of NAP the analysis of required skills was arrived at intuitively through 'common sense and personal reflection', and not through a psychological or social theory. Jon Ogborn's extended summary explains the kernel of the NAP course:

"We began by slowly assembling a list of what might be called important kinds of skill that someone learning or using physics after he [or she] leaves school ought to have begun to develop. Some skills are skills of the hand, such as being able to make an oscilloscope work. More are skills of the mind. Our list included as important items:

using basic ideas to explain particular complex phenomena;

recognising and using scientific terms and, more generally, being able to talk scientifically;

being able to read books and articles and learn from them;

knowing what scientific arguments are like, and being able to cope with their complexity and the need for clarity;

using and understanding the language of mathematics and being fluent in its notation (not wanting to cancel the d's in dx/dt, for example);

translating information from one form to another, particularly into and out of graphical form;

making rough guesses and estimates, and getting intuitively at what kind of solution a problem might have;

thinking and acting alone, being responsible for one's own decisions but also being able to communicate them."[55]

Many, but by no means all, of these skills are characteristically developed in the NAP course using carefully designed experimental work, where the close harmony of experiment and theory means that most of the course has to be taught in a laboratory. The emphasis on experimental work and the related cost of apparatus would become important factors in the decisions by schools to adopt or reject the NAP course after publication in 1972 .

So, against the background of a 'fearful timetable' the NAP team began to plan the conceptual structure of each of the units that would make up the course in preparation for the first schools trials starting in September 1968: "The selection [of physics topics] slowly took shape over two years, as we found out what we had time for and what seemed to work."[56] As with the other A-level projects the feedback from the first trials schools greatly influenced the timing and order of the coursework. Twenty-five trials schools were selected initially and they were grouped regionally around London, the east and west Midlands, and Yorkshire. The geographical groupings were supposed to provide a focus where ideas and information could be easily exchanged. The schools were chosen to maintain a balance between various types, some teaching NOP and some teaching traditional physics courses. Most of the LEA's selected schools with strong physics departments despite Black and Ogborn's wish to use 'typical schools' in the trials.[57]

Figure 2

Nuffield A Level Physics - The Three Strands of Physics

Electricity, Fields, Action at a Distance

Conduction; charge carriers; current and potential difference; electrical energy. Electric chage stored by capacitors.
Unit 2

Electric field; gravitational field; G; inverse square law; gravitational potential; electrical potential.
Unit 3

Electronics; reactive circuits
Unit 6

Magnetic field - electromagnetic induction; transformers; inductors; motors
Unit 7

Electromagnetic waves (simple description). Constancy of c; relativity effects.
Unit 8

The Nature of Matter and Atoms

Deformation and fracture of materials; Structure (X-ray evidence); strength; composite materials
Unit 1

Electrons; energy levels (electron-atom collision evidence)
Unit 2

Ionic bonding; structure; forces between and energy stored by pairs of ions
Unit 3

Radioactivity; Rutherford atom; Periodic Table; photons E=hf
Unit 5

Waves; particles; atoms. Duality for photons and electrons. Atoms as standing wave systems. Uses of wave-mechanical ideas.
Unit 10

Motion and the Analysis of Change

Dynamics; energy changes. *Unit 2*

Exponential decay of charge on a capacitor
Unit 2

Waves: superposition; the electromagnetic spectrum; mechanical waves; example of theoretical calculations of wave velocity. Oscillations: anaalysis of simple harmonic motion; resonance; standing waves.
Unit 4

Exponential decay; $\frac{N}{N_0} = e^{-kt}$
Unit 5

Optics: diffraction; gratings; polarization. Brief account of time dilation.
Unit 8

One-way and two-way processes; world fuel resources; statistical model of heat flow; absolute temprature.
Unit 9

90

In all, about 500 students started the NAP course in September 1968 and a further thirty-three schools were added in 1969 during the second year of trials: "Teachers from 31 schools and 2 Colleges of Further Education met us in July [1969] and began the course in September 1969. The students in these schools, together with the new first year students in those schools which started in September 1968, give a total of 1200 students (98 teachers) taking the new first year. The new schools have a broad geographical distribution; there are [now] groups in the North West, North East, West Midlands, East Midlands, Yorkshire, East Anglia, London and South East, South Wales and in Northern Ireland."[58]

The first NAP briefing conference for trials teachers was held at the University of Birmingham from 22-26 April 1968, and in May the first Newsletter was circulated to keep everyone in touch with developments which affected the running of the trials. A notable feature about the twenty-one Newsletters distributed by the NAP team between May 1968 and December 1971 is the large number of references that are made about the supply and cost of equipment. The use of apparatus in experimental work is fundamental to the teaching and learning in the NAP course and much of this experimentation is designed to enable the students to investigate the relationships deliberately interwoven into the course materials. Students are encouraged to participate actively in class experiments and demonstrations.

It is naive to associate NAP with such all-embracing terms as 'practical work' and 'using apparatus'. The NAP team had many discussions on the meaning of practical work in physics and they tried to dissociate the traditional idea that there was one uniform kind of experiment used to reinforce learning.[59] For instance, in several first-year NAP topics, students are asked to carry out different but related experiments and then communicate the results to the class:

> "The first comes early in the course and we found in trials that these first experiments and reports were painful: descriptions were confused and data ill presented and no one could tell whether two students who had done similar work had got similar or conflicting results. The pain had its effect, though, and students soon got better at reporting back. Teachers had to be warned of this and were encouraged to help the class through the first stage until confidence and ability grew."[60]

TABLE 2: A Summary of the General Aims of NAP

The aims are intended to imply practical objectives to be developed in the course and tested by examination.

1.Learning in the Future:
Students have an increased need to understand science, and be flexible in their future careers.

2. The Language of Science:
Students should be able to recognize and use scientific language and make connected arguments.

3. Learning New Ideas:
An introduction to ,say, quantum physics (not previously taught in schools) and a full treatment of ideas like charge, field and potential will assist learning in future.

4. Reading:
Students will become better at extracting knowledge from books and journals.

5. Arguing, Estimating and Communicating:
Students should be willing to argue, discuss, have patience and tolerance and use orders of magnitude when reporting to the class on their reading and experimenting.

6. Mathematics:
Emphasis is placed on the mathematics of rates of change $\frac{dy}{dt}$ and $\frac{d^2y}{dt^2}$.

Numerical methods are adopted. Proportion is widely used.

7. Independence:
NAP seeks to increase the student's ability and willingness to become more independent and self sufficient . Learning to inquire is encouraged.

8. Understand Physics and How it Works:
The student should be able to take constructive, relevant steps to solve problems.

9.Translating Information:
A special emphasis is placed on helping students translate information between graphical, verbal and numerical forms.

10. Interest and Enjoyment:
The course aims to develop confidence and delight in as many students as possible.

At other times the students all carry out the same experiment in order to make an idea concrete and visual; for example, the Unit 2 exploratory experiments using a capacitor, a battery and a milliammeter. This was not conceived as 'discovery' but "....to contrive occasions for students to think for themselves, with and without apparatus, in a variety of ways with different amounts of help."[61]

On occasions, in the first school trials, the students regarded some of these explorations as a cheat and said in effect 'Please tell us what to find and we will cheerfully find it for you'. The NAP Organizers responded by changing these experiments into student demonstrations. For example, in part of Unit 7 *Magnetic Fields*, the students set up demonstrations using oscilloscopes and signal generators to generate the effects of electro-magnetic induction and Faraday's Law. For the time, these student-led talks and demonstrations were a major innovation into A-level studies. Of course, there are many examples in the NAP course of teacher-led demonstrations based on apparatus. The heuristic 'discovery learning', so readily attributed to NOP, was only fully available in the NAP course during the time allocated to the two individual investigations.

A characteristic of curriculum renewal in physics is the constraint, keenly felt by Black and Ogborn, of developing cost effective equipment in time for trials schools' teachers to use the apparatus confidently with the students. Novel prototypes were constructed by Foxcroft and Harrap working together in the science laboratories and workshops at Rugby School and by the Joint Organizers using facilities at the University of Birmingham. Black and Ogborn arranged a few meetings with representatives of the Scientific Instrument Manufacturers' Association where the untried equipment was discussed, amended and eventually made into a commercially viable product.[62] Inevitably, there were manufacturing problems and often equipment was needed in the schools at short notice. The Marketing Director at Griffin and George Ltd., Birmingham, T.M.Auld, recalled that communication between the O-level Nuffield curriculum development teams and the manufacturers was poor. However, by the time NAP was being developed the links between the Organizers and equipment manufacturers were forged by personal contact. Eventually, the exchange of information was often made by telephone.[63] Important advances had been made to overcome the feeling of secrecy so apparent in the earlier O-level apparatus developments.

At about this time, 1967-68, the Nuffield O-level projects, particularly NOP, were being criticised for their 'pure science' academic approach and their lack of regard for technology and applied science. This view is debated at length by McCulloch, Jenkins and Layton in their book *Technical Revolution?*: "For at least the past century and a half academic and theoretical 'pure' science has generally taken precedence over applied science and technology in terms of status and resources and this has been reflected at the school level."[64] In a later analysis McCulloch identifies the NFSTP O-level initiatives as relating to an 'elite vision' of academic school science which superseded the idea of 'education for leadership' apparent in the grammar schools and independent schools in the 1950s.[65]

The sociologist, Michael Young, also argued that the linking of the NFSTP to O- and A-level sustained the academic and non-academic divide and created an elite form of physics based on 'laboratory knowledge', and as distinct from technology as was workshop or factory knowledge.[66] Young critically referred to the Nuffield physics projects as 'technically sweet' science and also emphasised their dissociation from applications and from the majority of students in schools: "The failure of academic science (pre- and post-Nuffield) for the majority is explained either within terms of conceptual difficulties or in terms of the pupils' lack of ability."[67] Sparkes was more direct: "Has not this situation come about because of those who think that school physics is only concerned with energy, force, momentum, fields, wave-particle duality, statistical thermodynamics and all the other nonsense of the Nuffield brigade? I am not depressed. School physics is about cars, computers, hi-fi, hot water systems, greenhouses and sailing dinghies, and these can be taught effectively by the physics teacher to a wide range of abilities."[68] Unfortunately, McCulloch et al and Young make only passing reference to the Nuffield A-level projects and do not mention the 'applied material' carefully interwoven into these courses. Sparkes conveniently excludes those parts of NAP with an applied bias.

In NAP, for example, the Joint Organizers were acutely aware that more A-level students studying physics became engineers than took up pure science[see Table 3]. Therefore Black and Ogborn went to considerable lengths to include materials that were externally relevant and which concentrated on applied physics:

1. Unit 1 deals with materials like steel, concrete, fibre-glass and polymers. The Organizers sought help from university departments and commercial organizations like British Aerospace (then called the British Aircraft Corporation).

2. Unit 6 uses a systems approach to look at the applications of electronics. Once the student has established the output characteristics for given inputs, the 'black boxes' can be linked together to make devices that detect fire or count bottles on a production line.

3. Unit 7 is nearly all based on the applications of electromagnetism. This self-contained Unit concentrates on electrical machines and leads to a minor 'end-point' involving induction motors.

4. Unit 9 ensures that the work on thermodynamics discusses the need to conserve fossil fuels and indicates practical applications of the Boltzmann factor in, say, explaining how to get energy out of hot materials.

5. *Physics and the Engineer* is an NAP course book that collects together a number of articles from an applied science journal.

6. The NAP Examination reflects this work on the applications of physics. It is a deliberate policy on the part of the Examiner to set questions in this area.

Keohane coordinated meetings between the A-level Organizers to ensure that applications in physics were included in all A-level projects. In addition, Dr. Tony Mansell[69] was appointed to join both the NAP and NAC teams to specifically develop the applied aspects of the Nuffield A-level sciences:

> "We do not propose to graft applied science on to these schemes, like some extraneous limb, but to try to encourage a method of teaching in which the pure and applied stand as co-equals."[70]

Upon completion of NAP in 1972, Tawney pointed out that despite the inherent difficulty that traditional teaching styles and teacher training emphasized pure physics, the NAP course had successfully incorporated ideas with an engineering flavour.[71] Although, with hindsight, Ogborn believes that he and Black wrote too little applied science into the NAP course materials the issue was not neglected and for its time made a significant contribution to the inclusion of applied science in A-level physics courses.[72]

Table 3 Statistics for Physics Education – Summer 1967
(From: *Statistics in Education*, HMSO, 1969)

1. School

	Candidates	Passed	%Passed
O-level Physics	96 000	58 000	60%
A-level Physics	42 000	28 000	67%

2. University

Entrants	Subjects using Physics	
43 000	2 000	Physics
	9 000	Engineering
	1 500	Medical/Dental
	800	Agricultural/Veterinary

3. Further Education

Students	Engineering and Technical Courses	
550 000	800	Physics
	2 800	Applied Physics
	21 000	Other Sciences
	14 000	Agriculture
	21 000	Medical Health

In order to accommodate these demands being made on the NAP project during 1968-69, Black and Ogborn increased their team membership to include:

- Tony Mansell to work on applied aspects of the course,
- Bill Bolton to act on school contacts and help with general administration and equipment development,
- John Harris to help with equipment development,
- Philip Lawton to undertake an on-going evaluation of NAP.

As noted earlier, Keohane was keen that the NAP project tried to match, in part, the sophisticated evaluation procedures being carried out by Peter Kelly in the NAB project. So in 1968 Keohane negotiated a grant of £10,000 from the Schools Council for an 'on-going' evaluation of NAP over a two year period. Philip Lawton was seconded from Garnett College of Education for Teachers in Further Education at Roehampton to carry out the work and he joined the NAP team in July 1968. [73]

Black and Ogborn had already set up a system of Newsletters to provide contact with trials schools. Out of visits by team members and the regional meetings of the trials teachers (held about twice a term and lasting one day), from teachers' written comments on the draft Teachers' Guide and through class tests, a substantial amount of information was being fed back to the Joint Organizers. Initially, Lawton concentrated his efforts on student questionnaires and analysing the data from class tests. Unfortunately only a few 'in house' reports were circulated during 1969 and no firm conclusions reached. Paul Black recollects that these evaluation reports were 'partly useful' but that there developed a communications barrier between the NAP Organizers and Lawton: "He never seemed to be able to satisfy us and we never seemed to be able to satisfy him."[74] Certainly the Joint Organizers did not receive the evaluation support expected by the Schools Council. In the event, Lawton did not honour his obligation to write and publish his findings for the Schools Council. Swain's research into evaluation studies on NAPS and their comparison with other A-level projects records: "It is indeed unfortunate, however, that such a large sum has not in any way been accounted for in terms of publications and reports [on NAP]."[75]

During January to April 1968 Black and Ogborn wrote and printed a 'hurried first trial version' of NAP teachers' guides and whilst the first year trials were in progress the team produced student question books, experimental guides, student background booklets, supplementary or correction pages for the teachers' guides, applications of physics supplements and any other material as demand arose.[76] The second year trials, starting September 1969, used a second trial version of these materials written in the light of the information fed back from the schools and from Lawton's evaluation. As in the case of NAC, special provision was made for some schools who had taken the Nuffield O-level examination to start the A-level course in September 1970 using the trial materials provided at cost price.

As the time approached to write the final version of the NAP course for publication in 1971-72, more of the work devolved upon those team members seconded full time. In particular, Jon Ogborn assumed much of the responsibility for writing the final version of the NAP course whereas Paul Black became more involved in publicity and with the delicate negotiations with the Oxford and Cambridge Schools Examination Board:

> "We [the NAP team] all agreed that one hand should write the NAP course for final and there was only one hand that could write good clear stuff at that speed and that was Jon."[77]

Jon Ogborn resigned from his post at Worcester in 1969 and returned to London as a Senior Research Fellow at Chelsea College from where he was seconded to complete NAP. Working at the Chelsea College annex in Lillie Road, London, and in close proximity to the NFSTP publishing unit run by Bill Anderson, Ogborn spent many hours completing the final version of the NAP course. He was surrounded by feedback comments from a wide range of sources: criticisms from the NAP team, comments by trials teachers written on each page of the Teachers' Guides (each page was then re-collated to generate a complete set of comments), digests of feedback comments prepared by Bill Bolton, letters from trials students (these were the first to be read because they gave an overview to the whole Unit), Lawton's information from unit tests and examinations, and, finally, the basic structural changes that emerged from discussions amongst the team.[78]

All this information gave Jon Ogborn some guidance about priorities - the choice of areas in which to expend scarce resources of re-writing time. For example, it was realized within the NAP project that Unit 8 on physical optics was not functioning well in so far as student interest was concerned:

> "Because the material of this unit [Unit 8] was not novel, or organized in any novel way, it seemed unlikely that confusion was the source of the difficulty, but rather that it might be that the material seemed to cohere badly with other work. In rewriting, this material was incorporated within a wider perspective, by putting it with work on electro-magnetic waves."[79]

Furthermore, it became apparent that more text material was needed in the second year: "*Change and chance* [Unit 9] emerges here as 'difficult', and has been made easier; while *Waves, particles and atoms* [Unit 10], perhaps surprisingly, seems not to be difficult, and has remained substantially unmodified."[80] As it turned out, Units 9 and 10 were re-written as combined Teachers' and Students' Guides, another important innovation for the time, and in rewriting Jon Ogborn spent about 4-6 weeks on each of the ten units. During this time the Joint Organizers kept in close touch despite the problem of Black remaining in Birmingham and Ogborn working in London.

The NAP project was finally launched during the ASE meeting held at Stirling University from 28-31 December 1971. The publishers, Penguin Books Ltd., made available inspection copies of Units 1 to 5. Equipment manufacturers displayed and demonstrated the new apparatus developed for the course. The remaining books for Units 6 to 10 and supplementary materials were published during the Summer and Autumn of 1972. Black and Ogborn calculated that: "The Nuffield Advanced Physics project was given resources equivalent to some 15 man-years of effort, together with the further contribution of trials of its materials with over 1000 students and some 70 schools of every type."[81] The Nuffield Trustees had budgeted £333,110 to develop the three A-level physical science projects and by July 1971 this had risen to £384,599. Keohane recalls that the NFSTP was not too precise in the way that the money was divided between the three projects and he estimates that about half of the £400,000 (approximately) was spent on both phases of NAP.[82]

In this atmosphere of frenetic creative activity Paul Black assumed direct responsibility for the negotiations with the Oxford and Cambridge Schools Examination Board, the institution assigned by the Secretaries of all the GCE Examinations Boards to administer, on their behalf, the experimental examinations in NAP. Earlier, Dick Long had made tentative proposals for an A-level physics examination and held discussions with McKenzie and King at the Oxford and Cambridge Board.[83] Once again, Black and Ogborn decided on a fresh start; their proposals were novel in style and this led to 'hard discussions' with the Board.[84] Along with other Nuffield A-level projects, NAP used a variety of styles, types of questions and assessment procedures that "....reflect and reinforce the aims of the teaching."[85] For example, the format of the first trial examination, held in the summer of 1970, lists the diversity of the examination and the implied administrative difficulty for the Oxford and Cambridge Board:

FIRST THREE HOUR SESSION
1. Coded Answer Paper, 40 questions, no choice, 1 hour.
2. Comprehension Passage, 6 questions in 1 hour.
3. Paper on Optional Topics in Year 2, one question out of 6, 40 minutes.

SECOND THREE HOUR SESSION
4. Short Answer Paper, 9 questions, no choice, 1.5 hours.
5. Long Answer Paper, 3 questions out of 6, 1.5 hours.

PRACTICAL WORK ASSESSMENT
6. Teacher Assessment of Second Year Investigation.
7. Practical Examination, 8 short exercises, 2 hours. [86]

Black and Ogborn deliberately composed the examination to be a variety of papers using different assessment techniques. In many parts of the examination choice was restricted to ensure a fair sampling of the syllabus and to allow examiners to set questions of different types and different levels of difficulty. The Options Paper, item 3, was initially set for those trials schools that had difficulty in completing the course, especially in Units 9 and 10 near the end of the course. These materials were pruned and rewritten in the final published books, therefore the Options Paper was removed from the final version of the examination structure in which items 2 and 4 were interchanged. (The final examination profile for NAP is given in Table 4 below.)

TABLE 4
Structure of the Nuffield A-level examination

Examination session	*Title of paper*	*Time/Hrs*	*Structure of paper*	*Weight in assessment (%)*
First	Coded answers	1.25	40 q, no choice	21
	Short answers	1.5	8 q, no choice	21
Second	Long answers	2	3 q, chosen from 6	21
	Comprehension	1	6 q, no choice	10.5
Third	Practical problems	1.5	8 q, no choice	16
Teacher-assessed investigations – taking the equivalent of two weeks of the A-level classroom time				10.5

As the chief architect of the NAP examination procedures Paul Black had to develop an understanding of the internal workings and informal style of the Oxford and Cambridge Board: "It took me some time to get used to their style because they are very different from the JMB in their [smaller] size, their tradition and historical development."[87] Black recalls that in the 'long run' the Board was receptive to new ideas and that eventually they developed a relationship that worked to their mutual advantage.

For the NAP team the discussions revolved around the appointment of sufficient Awarders and Examiners, and arranging suitable training meetings, to provide long-term stability to the examination structure:

> "The main argument appears to rest on a comparison between O and A level procedures. I [Black] have consulted O-level awarders, and in particular Mr. John Lewis, about their procedures, and find that they are not happy with it. The system used puts enormous pressure on one or two people because they have to revise substantially the proposals that are collected; Mr.Lewis also tells me that they would very much like to meet with their question setters to discuss the questions proposed. His fear, that the present procedures put pressure on a few who are not able to communicate with, and so

> train, possible replacements, mirrors my own fears on the A-level development."[88]

The position for the NAP team was exacerbated by the subtlety of the questions, in comparison with traditional A-level, as well as the novelty of the practical assessment work carried out by the physics teachers and the external moderation at the Board.

On the other hand the Oxford and Cambridge Schools Examination Board found that the ‘bittyness’ of the NAP examination produced a considerable deficit:

> “It is only fair to our own Board that we who run the day-to-day administration should be able to justify the expenditure of Board funds on a project where the course content is not under the jurisdiction of the Board, instead of using the same resources on the Board's own activities."[89]

In any event the Nuffield Foundation's established policy, having the revision of examinations as part of its brief, was to expect some deficit payments; "...but the boards themselves should also be expected to make some changes to examination procedures which are educationally desirable but not profitable, and I [Brian Young] hope that we can make it very clear to them that the Foundation is not their 'milch' cow."[90] Black instigated a projection of costs for 3,000 students and the Board found that income and expenditure were approximately equal.[91] By 1974, only three years after this cost estimate, NAP examination entries had risen to 3,829 and by 1984 the entry exceeded 9,000 candidates.

In retrospect, Black found that some of the Oxford and Cambridge 'in-house' features were very useful to the NAP project. The Board provided an annual teachers' meeting, which eventually grew to two meetings, so that Examiners and teachers could discuss the previous year's examination and future developments in the NAP course and examination. These meetings would eventually become an important source of feedback in the revised NAP course . On the other hand, in the seventeen years that Paul Black was to be responsible for one side of the NAP examination, the Board's informal basis did not provide established subject committees to keep reviewing the syllabus and appoint examiners. In contrast NAB and NAC were guided by specialist subject committees at their coordinating boards. The inherent weakness of the informal approach did not matter as long as continuity was maintained through Black's involvement with the NAP examination.[92] However, in a then future enterprise, Paul Black will extend his involvement in assessment and testing through his chairmanship of the Assessment of Performance Unit (APU) [93] and the Task Group on Assessment and Testing (TGAT)[94], so that by 1986 he is forced through pressure of work to finally relinquish his direct involvement with the NAP examination. The vacuum created by his move was filled by a 'subject committee': The Nuffield Post-16 Physics Group, consisting of four Awarders, two teacher representatives, one member from the NCCT and one member from the Examination Board. The Group began their work in 1989 .

As indicated earlier, the four Nuffield A-level projects carefully considered the part that practical projects might play in an A-level course and as a result they created innovatory assessment methods, using internal teacher assessment, as part of their examination procedure. In time these ideas were promoted through the Schools Council and adopted by CSE-level courses: "Unfortunately at CSE level, the clear definitions of project work laid down at A-level [Nuffield] were not always adopted, with the result that inclusion of project work in a CSE course was not always indicative of an element of practical work being present."[95] Eventually, in 1986, both the O-level and CSE examinations were replaced by GCSE assessment procedures which included the widespread introduction of teacher-assessed techniques, readily traced to the Nuffield A-level innovations. Philip Halsey, who, it is interesting to note, would later become Chairman of the School Examinations and Assessment Council (SEAC) on its foundation, wrote from the Schools Council, in September 1970, to Kevin Keohane:

> "My immediate purpose in writing is to seek a Nuffield paper on A-level physics syllabus construction which I understand from Professor Allanson exists and might be useful in relation to the Council's likely attempts to establish new sixth form examination syllabuses, papers, assessment techniques, etc., for all the normal sixth form subjects."[96]

From the outset, Paul Black, in particular, and Jon Ogborn argued trenchantly for the inclusion of two short individual investigations into the NAP course. Black's conviction was fortified by his involvement in a practical assessment exercise carried out on a trial basis for the JMB and, of course, his work in this area with university students.

Prompted by less enthusiastic team members, Black and Ogborn anticipated considerable logistic difficulties and the problem of convincing trials schools that such practical investigations were possible.[97] In a letter to the NFSTP Co-ordinator, Black and Ogborn list their problems:

"(1) convincing ourselves and schools of the value of this work.

(2) finding out what conditions make it feasible, and how much equipment etc needs to be at hand.

(3) building up experience of telling good from poor work - not always easy where an imaginative hard working 'failure' may be worth more than a 'successful' but uninspiring piece of slog.

(4) working on assessment methods for the A-level exam."[98]

They proposed a mini-trial of two or three schools almost before the NAP project had begun: "This was a trial to solve the Existence Theorem: could investigations be done at all within a limited remit compared with the big half-term projects. Can anything decent be done in a length of time like two weeks? This trial enabled us to stand up in front of our continuous trial schools and say 'This is our proposal and here are some teachers who fitted this work into their ordinary teaching.'"[99] Black and Ogborn were positively keen on a limited remit. They did not want projects that were solely the construction of devices, as was possible in NAPS and NAB, but instead they intended that the emphasis should be on investigations carried out by the pupils:

> "In these, each student works on a small novel problem of his or her own, not necessarily (or even usually) closely related to other experimental work in the course, for which the choice of apparatus and the devising of the method is left to the student. Experience has so far shown that these short exercises do arouse interest and enthusiasm and do develop individual involvement with a problem in physics."[100]

The late Bill Trotter, who for many years dealt with the moderation and organisation of about 9,000 investigations, was convinced that the enjoyment aroused in this type of work is central to the role of physics education.[101] This sense of involvement is not confined to the A-level pupils. Teachers and physics departments also benefit from the activity. For instance, Trevor Sandford "....used to enjoy the fortnight of investigations with a Nuffield A-level class because I didn't have any lessons to prepare! I ended up, however, doing far more work, running around getting apparatus, discussing, questioning, probing, negotiating, advising, acting as a buffer between the ever-demanding student and the hard-pressed technician."[102] School physics departments also benefit from the cumulative effect of investigations where apparatus is purchased or developed to carry out the investigation and some ideas can be used to extend the teaching of NAP coursework.[103] The physics section in School Science Review is full of 'fine-tuning' ideas for teaching and many have been developed through practical investigations. The influence and evolution of twenty years of NAP investigations is further illustrated by Ken Dobson's article in Physics Education. He identifies the 'sideways' influence into other GCE A-level syllabuses and the 'downward filter' into all GCSE science courses.[104]

During the late 1960s and early 1970s much of Kevin Keohane's coordinating correspondence with the Schools Council dealt with the introduction of NFSTP examinations and in particular the role of project work as part of the A-level assessment.[105] One of his concerns was the burden that might be placed on a pupil following three experimental sciences all requiring projects. The topic was discussed fully by the Schools Council Examinations Committees but they felt that projects were a curricular rather than an examination matter and that it was up to the schools to urge the GCE Examining Boards to frame their requirements accordingly. In reporting back to Keohane, Robert Sibson commented: "In CSE there is now [1970] something of a recession from the high tide of project work when some candidates were doing four or five, and it is increasingly recognised by the CSE Boards that schools must be left with freedom to take their own decisions in this connection."[106] This issue has never been satisfactorily resolved, so that even in the 1990's, with project work widely available, candidates wishing to undertake a joint project in Science are subject to the following constraint: "A school wishing candidates to undertake a joint Investigation and to provide individual assessments based on such an Investigation must seek approval of the board [Oxford and Cambridge] *in advance*. Joint Investigations are not encouraged."[107]

The Nuffield A-level Physics project arose and developed in an atmosphere of debate about broadening the education of sixth-form students. When the Schools Council was first established, in 1964, education 16-19 was one of its priority areas. The Schools Council publication, Working Paper No.5, 1966, (Chairman Sir Desmond Lee) proposed that schools could choose 'half-subjects' or 'ancillary subjects' in the A-level examination:

"'A' levels were to be divided into 'major' and 'minor' subjects, so that a pattern of two majors and two minors could make up a more balanced curriculum than three equal 'A' levels, and yet leave adequate time (assuming of course that it would be used) for unexamined general studies."[108]

A group of HMI's went to considerable lengths to translate these ideas into a feasible overall pattern of work based on the assumption that "....examinations could be designed which would be educationally suitable, and capable of meeting user requirements, at the various levels of attainment likely to arise if the new pattern of major and minor courses is to meet the needs of most pupils likely to enter the sixth forms within the foreseeable future."[109] Able pupils should study two major and two minor subjects and less academic pupils might take more minor subjects but fewer majors, and all pupils would take General Studies. There was a total rejection of the proposals from the schools and from SCUE. The schools felt that the minor subjects were too much like A-level and therefore unsuitable for the wider spread of ability in the sixth form. SCUE called for further information on minor subjects with a view to university admission.[110]

Professor Sir Nevill Mott was so alarmed that he organised a high level meeting at Caius College, Cambridge, on 14-16 September 1967. [111] The meeting was proposed by *Nature* and reprints of the proceedings were widely distributed. Most of the time was devoted to discussing a broad-based continental pattern of, say, five A-level subjects equally weighted and divided into two categories, basic and optional. As expected, there was no overall agreement. However, the Caius meeting did agree that common core syllabuses should be devised immediately .

After the Caius meeting John Dancy, the Headmaster of Marlborough College, came to the conclusion that:

"(a) We are going to have a hard job simply explaining what our [Schools Council] new proposals mean. It was depressing how many university scientists present were unaware of the facts, let alone the importance, of the Nuffield A level Physical Science programme.

(b) If that meeting is representative, university scientists want a broader sixth form curriculum and are prepared to pay the price themselves either by cutting their syllabuses heavily or by providing a fourth year for more students."[112]

McCulloch sees Dancy's, and Lee's, interest in these A-level and science curriculum reforms as a demonstration of "....the ability of public and grammar schools to adapt to the changing needs without sacrificing their established and distinctive traditions."[113] Certainly, the public and grammar schools invested considerable amounts of time and personnel to achieve these ends.

The universities, according to Lawton, tended to speak with two voices on these issues: "....one, a genuine concern for general, liberal education, expressed by Vice-Chancellors and others; two, a more parochial insistence, by admission tutors, on 'standards' of specialised knowledge for those who wished to embark on a first degree programme."[114] So it was possible for the universities to agree to the Schools Council proposals for a broader curriculum in 1966 and then to reject more specific ideas in the future.

Faced with these reactions, the Schools Council and SCUE set up a joint working party during 1968 with the energetic Professor Jack Allanson as Chairman. Eric Briault was a member of this group and he also chaired the Second Sixth-Form Working Party of the Schools Council. Both working parties produced a joint, unanimous recommendation advocating an A-level course in five subjects in the first year sixth form at qualifying level(Q), narrowing to three in the second year(F), the so-called Q and F proposals. Not surprisingly the schools attacked the idea of examinations in three successive years, O-level, Year 1 A-level and then Year 2 A-level. and felt that the Year 1 standard would be so near O-level as to be meaningless.[115] The Council rejected the Q and F ideas in 1970. The working parties continued to explore possible changes in the sixth-form curriculum and examinations which resulted in the publication, during 1972-73, of Schools Council Working Papers 45, 46 and 47, which maintained recommendations for a 5-subject A-level. Pupils who normally chose three A-levels would be expected to select five subjects: three at Normal(N) level, with N-level roughly half an A-level, and then spend more time on the other two subjects at Further(F) level, with F-level about three-quarters of an A-level. Three N plus two F would theoretically be the same as three A-levels.

Geoffrey Caston, a Joint Secretary at the Schools Council from 1966 to 1970, wrote to the NFSTP Co-ordinator to allay fears about the Schools Council initiatives circumventing the Nuffield A-level projects: "I would hope that the particular impact upon the Nuffield projects would be very much in the minds of the Working Party, and we will try to ensure that this is so. On the other hand, my personal opinion is that it is extremely unlikely that there will be a general change in the sixth form pattern until well after 1972, so that I don't really think there is any chance of your project being overtaken by events."[116] There was a special relationship between the Nuffield Foundation and the Schools Council and there was also an extensive correspondence between officers at the Council and the NFSTP Coordinator. Furthermore, people like Professors Jack Allanson and Clifford Butler were actively involved in both Schools Council and NFSTP activities. So at this time the NFSTP was in a powerful position to secure its interests in the sixth-form science curriculum.

The N and F debate rolled on and on, with Paul Black becoming involved with a parallel NFSTP study on the implications for the Nuffield A-level projects . Eventually, in July 1979, the Labour Government decided to retain A-levels in their current form and to terminate the N and F proposals. The then Secretary of State, Shirley Williams, announced that there was not enough agreement on the alternative proposals, in a period dominated by alleged declining standards in schools and with the universities forced to produce honours graduates in only three years.[117]

Inevitably, the results of Mott's Caius meeting and the various Schools Council proposals were aired at the Nuffield A-level Joint Committee for the Physical Sciences and the Chairman, Mott, expressed the view that if a five A-level pattern was adopted there should be a physical science course equivalent to two A-levels. Black and Ogborn, deeply involved in the planning of NAP, reacted strongly: "We hope that you will understand that we would be reluctant to spend our time and effort on constructing a course if it is to be the policy of the Science Teaching Project that this course [NAP], or any course like it in physics as a separate subject , is to disappear in the revision of the sixth form curriculum."[118] Keohane quickly reiterated that the Nuffield Foundation had a policy to provide courses where there is an established need and that clearly NAP was in that context. Furthermore, he reinforced the view that the NFSTP "....have to accept that Physical Science is likely to take a very long time to become widely accepted and a subject as well established as Physics should have no need for concern about the growth of an experimental course of this kind."[119]

Mott's reply was even more forthright: "If the 5 A-level pattern really ever becomes at all common, then it would be sensible to take your physics course [NAP] and the Nuffield chemistry course and examine very carefully whether there was any material which might be taught jointly, in order that the standard of knowledge of boys [sic] leaving the sixth form should not drop too far. This might be a more sensible solution than taking the present physical science course [NAP] and treating it as a double subject. But the alternative would be so to emasculate Spice's course, would you not agree, that it could not conceivably be thought of as an introduction to university physics?". [120] Showing a sense of prescience, Black and Ogborn requested that as part of the NAP work they should explore the possible nature of a shorter physics course suitable for use as one of the 5 A-levels. Procrastination in reaching a consensus about the nature of A-level curriculum changes stopped any further developments. However, twenty years on, as a consequence of the revision of NAP and the introduction of AS-levels, the Nuffield-Chelsea Curriculum Trust (NCCT) prepared a shorter Nuffield AS-level physics course that was approved by the SEAC in 1991.

The turbulent history of the Nuffield A-level Physics project illustrates the kind of co-operation, compromise and partnership required for successful A-level curriculum development. Central to these issues is a productive partnership which allows change in the schools and universities to accommodate the generally held desire to broaden the work of sixth forms without destroying the specialist foundation on which British university work characteristically depends. Almost one year after Long's resignation Nyholm called for change by the universities.

> "It is intolerable for a university chemistry department, for example, to talk about the need for a "broad general education" at school, and then insist on good A-level passes in chemistry, physics and mathematics. Universities must accept the need to teach more of the introductory work themselves if students at school are to have the opportunity to study a wider range of subjects."[121]

Earlier discussions illustrate how Mott's Study Group in 1964 and Black and Ogborn's offer to create a reduced Physics A-level in 1968, anticipated something like AS-levels. However important, the universities represent one, and only one, of the demands currently being made on the post-16 curriculum. But at the time of the Nuffield A-level developments their influence and power were considerable. In this respect Long was right to offer some resistance to their pressures and Black and Ogborn wise to establish their positions with university academics from the beginning. Becher and Maclure were unable to find "....evidence of official university pressure on subject-based curriculum development."[122] The history of NAP and its evolution within the NFSTP provides considerable evidence.

Chambers, in his paper prepared for Long's 'resignation meeting' of 14 February 1967 , addressed one of the main problems in school-university physics. He identified the pruning of A-level syllabuses by different teachers and the problems this poses at university. Later, the 'drastic selection process' in the design of the NAP course exacerbated this problem: "It follows that Nuffield [NAP] students will be acquainted with fewer topics, terms and proofs of results than will students from a conventional course, although we [Black and Ogborn] hope that they might not differ so much in the number of topics they understand. Just because university teachers have for long adapted themselves to students whose acquaintance with ideas is fairly extensive (but not uniform), a substantial adjustment may be needed to deal with students whose course was intended to help them to understand a smaller number of ideas."[123] In addition, the Joint Organizers openly encouraged the trials teachers to be flexible and interpret the NAP course to suit their individual needs: "Teachers also seem to find it hard to tell from the [NAP] guides what is important, what can be treated lightly and what could be safely omitted....In general, we would like to encourage teachers to interpret the guides rather than follow them rigidly, using the material to stimulate thought and discussion as far as possible."[124]

Mott, heavily involved in events, saw a solution to this issue and was to write on 21 February 1967:

> "And as for schoolmasters pruning the course, we ought to make a core which they must *not* prune."[125]

In time, SCUE, under Mott's influence, would generate a large subject core for A-level Physics, all of which, it advised, should be incorporated into future A-level curriculum developments, including a revision to NAP . Clearly, many of the issues raised in the two phase NAP developments are still alive today.

Finally, it is worthwhile to ask the question: in what sense was the published NAP course an extension of Long's original conception? After publication, in 1973, Bryan Chapman wrote: "The award of the Bragg medal and Prize to Jon Ogborn and Paul Black for their work on the Nuffield A-level physics project will be applauded by all those who know anything of this project. No award could be more deserved. At the same time it is appropriate to recall that they were not the originators of the scheme. The basic structure of the course has changed remarkably little from that proposed by the original project organizer, V.J.Long. It would perhaps, at this stage, be nice to have some greater acknowledgement of his contribution to the success of the project, particularly from those who initially had such little faith."[126] No acknowledgement was published, except that written by Black and Ogborn in the NAP Teachers' handbook: "The Organizers are particularly grateful to V.J.Long, who originated the work of the Project, both for that early work and for his continuing criticism and advice, which has always been acute, sympathetic, and perceptive. The overall shape of the course owes much to his original conception of it."[127]

One of Long's more important contributions, though the circumstances may have been unintentional, was to bring the university views to a head. Even if Black and Ogborn had started the NAP project in 1966 it is likely that they also would have faced the same sorts of arguments from university physicists, or at least those based on syllabus content. How they or anyone else would have coped we can not say, but Long made a stand on principle, and even if he lost for pragmatic reasons, he made the point. The task of negotiating radical reform was actually made more possible following Long. The Foundation learned from the experience and provided much more supportive structures. The upheaval generated greater will by the universities to be constructive and co-operative in A-level curriculum renewal and so enhance the notion of partnership.

Long's insistence that school teachers should be at the heart of A-level curriculum renewal stemmed from his view that both syllabus content and teaching methods should be closely interwoven in development strategies. As it turned out, Black and Ogborn were able to build successfully upon that understanding. Their combined talents also built a sense of cooperative partnership between school and university interests, and in their joint organizership the partnership was seen to be there.

Apart from the notion that Black and Ogborn inherited ideas and people from the Long era, their course is not a simple continuation of Long's, for, in a sense, there was no course to continue. However, there were ideas that could be developed and good people to help carry out the developmental work. For example, the seed of an idea for Unit 6: *Electronics and reactive circuits* can be traced to a paper prepared by D.Read, one of Long's invited 'new hands' . Jon Ogborn picked out the idea and together with Geoffrey Foxcroft developed the unique systems approach to electronics, using 'basic units', that would eventually spread into other A-level syllabuses and even influence electronics teaching to younger pupils.[128] In these events, Chapman's comments have some force and this study goes some way in providing a full acknowledgement of Long's seminal work in NAP.

Clearly, a revolution had been achieved in the content and presentation of A-level physics, which was never to be the same again. To summarise the contrast brought about by NAP, the major headings from the 1971 London Board's A-level Physics syllabus, typical of the pre-NAP era, is juxtaposed with the Unit titles and major headings of the first NAP books in Table 5 (overleaf). A number of the London Board's syllabus topics have been included under one general heading. Of course there was no NAP syllabus as such - a dramatic enough change in itself.

The NAP project generated many examples of what Ogborn calls 'didactic transposition', i.e. "...that the construction of teaching material and the organisation of learning experiences necessarily involves the construction of a new, uniquely pedagogic entity which then has a life of its own, generating its own pressures, tensions and possibilities."[129] What we know now as Nuffield Advanced Physics is in part due to Long, in very great part to Black and Ogborn, but also to its life in the schools, and it is to that which we now turn.

Table 5: Comparison of London A Level Physics and NAP

Nuffield A Level Physics (1971) Section headings in published order	**London Board A-Level Physics (1971)** General syllabus topics not in published order
UNIT 1: MATERIALS AND STRUCTURE • the variety and behaviour of materials • X-rays and structure • stretching and breaking, Young's modulus • **UNIT 2: ELECTRICITY, ELECTRONS AND ENERGY LEVELS** • things which conduct • currents in circuits • electric charge; exponential change • stored energy; capacitors • electrons and energy levels **UNIT 3: FIELD AND POTENTIAL** • the uniform electric field; ε • gravitational field and potential • the electrical inverse square law • ionic crystals **UNIT 4:WAVES AND OSCILLATIONS** • waves of ,any sorts, electromagnetic waves • mechanical waves • mechanical oscillations, resonance **UNIT 5: ATOMIC STRCUTURE** • radioactivity and the nature of atoms • the Rutherford model of the atom, alpha scattering • exponential decay • new ideas and problems about atoms **UNIT 6: ELCTRONICS AND REACTIVE CIRCUITS** 1. electronic building bricks 2. circuits containing capacitance 3. circuits containing inductance 4. building electronic systems **UNIT 7 MAGNETIC FIELDS** • forces on currents • electromagnetic induction • flux near currents **UNIT 8: ELECTROMAGNETIC WAVES** • looking through holes • Spectra • electric waves • relativity **UNIT 9 CHANGE AND CHANCE** • one-way processes • the fuel resources of the Earth • chance and diffusion • thermal equilibrium, temperature and chance • uses of thermodynamic ideas **UNIT 10: WAVES, PARTICLES AND ATOMS** • photons, wave-particle duality • electrons, electrons as waves • waves in boxes, Schrödinger's equation • the scope of wave mechanics • **INDIVIDUAL INVESTIGATIONS AND PRACTICAL PROBLEMS**	**GENERAL PHYSICS** • momentum, motion in a circle, moments of inertia • pendulum, g, law of gravitation • elasticity, Young's modulus • friction, surface tension, barometer, viscosity • force and work, dimensions and units • kinetic theory (introduction) **MAGNETISIM AND ELECTRICITY (1)** • static electricity, electroscopes • potential, capacitors • current electricity, Ohm's law, Wheatstone bridge • potentiometers, voltmeters, ammeters **SOUND** • sound, wave motion, stationary waves • superposition, beats, echoes • resonance, vibrations in air and strings • Doppler effect • velocity of waves, frequency, wavelength • progressive and stationary waves (mathematics) • sound intensity • recording and reproducing sound **ATOMIC AND NUCLEAR PHYSICS** • radioactivity • structure of atom, constituents of the nucleus • isotopes • mass and energy, fission and fusion **MAGNETISM AND ELECTRICITY (2)** • simple magnetism, strength of magnetic field • lines of force, magnetic moments • Earth's magnetic field • electromagnetic induction • alternating currents • transformers and motors • electrolysis and conduction • cathode rays, X-rays, CRO • properties, uses of ferromagnetic materials • hysteresis • ballistic galvanometer, Weston cell **GEOMETRIC AND PHYSICAL OPTICS** • photometry, luminous intensity • reflection, refraction, refractive index • prism and lens formula, spectra • optical instruments, resolving power • wave theory of light, interference, • Young's two-slit experiment • polarisation, Newton's rings • electromagnetic waves, measurement of c • photoelectric effect, photons **HEAT** • temperature, thermometers • quantity of heat, specific heat • change of state • expansion, ideal gas, pressure • transfer of heat, cooling • thermocouple, measurement of temperature • first law of thermodynamic, radiation laws • kinetic theory of gases (detail) **PRACTICAL EXAMINATION**

CHAPTER FOUR
Dissemination and Diffusion - NAP in Schools and Colleges

Under Jon Ogborn's editorial guidance, the Nuffield A-level Physics project's *Teachers' handbook* expresses the wishes of the NAP team:

> "In our view, it is the business of teachers, not to follow some policy imposed from outside, but to think hard about the aims of what they are doing, and to experiment with a variety of methods [of teaching and the roles of teachers and students], in various mixtures, watching carefully to see what happens. Teaching is so personal a matter that each teacher will have to make the aims and methods his own, in his own way."[1]

Presciently, Kerr had realized some time before the first Nuffield O-level projects were published that the difficulties in changing teachers' attitudes and methods, and their natural resistance to change, would handicap the acceptance of the Nuffield ideas. He warned against teachers and administrators rejecting the project's aims before the results of carefully validated tests and trials were known.[2]

On this basis, Whitty and Young believe that such an "....invitation to teachers to suspend their taken-for-granted assumptions and examine critically their own practices would produce a transformation in the nature of their activities was ludicrously naive."[3] Naive or not, the intentions of the NAP project team and the reality of NAP materials and equipment in schools have substantially influenced the teaching methods, syllabuses, examinations, textbooks and apparatus used by teachers and pupils in A-level physics classes of all types and persuasions: in the NAP trials schools, in the minority of schools that fully adopted NAP, the majority that adapted NAP to their own ends and even in the schools that rejected NAP, but readily used apparatus developed for the project.

The first schools to experience the second phase NAP materials were, of course, the twenty-five carefully chosen first trials schools, involving 43 men and 10 women teachers and about 450 students (447 candidates sat the first NAP examination in June 1970). The schools were primarily chosen in geographical groupings roughly corresponding to the three development centres at Birmingham-Worcester, London and Rugby. The groupings were to ease communication problems and to enable ideas to be readily exchanged. At no stage did Black and Ogborn regard the trials schools as centres to assist in the planned dissemination of NAP - they were more anxious at this early phase to develop a good physics course.[4] There is some evidence, however, to suggest that NAC, and particularly NAB, were more aware of the potential role of trials schools in the dissemination of their projects.[5] A fourth NAP cluster formed around Dick Long and Bryan Chapman in the York-Leeds area, and there were two 'isolated' schools in Bristol and Suffolk. (A full list of all NAP trials schools is given in Appendix III.)

Seven of these first trials schools were involved in varying degrees in Dick Long's preliminary trials, 1966-67, and Jon Ogborn does not remember any adverse reactions from any of the 'Long schools'.[6] Otherwise, as in the production of the NAP course, Black and Ogborn made a fresh start and chose schools to meet their own needs. They wanted a broad spectrum of schools to enable a good confident trial and they wanted to include some of the, then, newly formed comprehensive schools offering A-level physics classes. They approached the LEAs, who generally selected schools where the physics department was known to be strong. On the whole, independent schools were eager to join the NAP trials and the Joint Organizers were able to select schools, often with the prior knowledge that there were good teachers involved.[7] The Joint Organizers were anxious to include some schools that had entered NOP candidates in June 1968 (about 1000 candidates) but these schools were few in number so the majority of A-level trials pupils had not experienced NOP.

The NFSTP undertook to provide the written teaching materials for both teachers and pupils and allocated a member of the NAP team to be responsible for advice. Teachers were expected to attend briefing conferences, lasting a few days, on three or four occasions in the period 1968-70, and there would be regular regional meetings. The main contribution from the LEAs and School Governors was to meet the cost of apparatus for NAP (£1,500) and, if necessary, the additional cost of NOP equipment needed in Year 1 (£1,500).[8]

Even before the trials it was apparent that the NAP teachers would need to be robust and flexible: "We [Black and Ogborn] were concerned to be sure that the schools would be able to make a 'fist of it'. For the first trials we were perfectly clear that we would be asking them to do things that would turn out to be impossible, and we didn't need too many schools which would collapse under that strain. We were bound to get it wrong, so the initial trials schools had to be those that were pretty solid and able to cope - the sorts of schools who would tell us that something was impossible and who wouldn't get themselves in a mess, but not schools that were so weak that almost everything was impossible. It had to be the really bad things that they picked up."[9]

Fred Archenhold was an NAP trials teacher at Huddersfield New College. This state grammar school had carried out trials in both NOP and the modern physics involved in the Studley experiment . Overall, Archenhold and the other physics teachers were impressed with the aims and spirit of the NOP and their trials experiences had prepared them for uncertainty and 'thinking on their feet'. Despite these credentials Archenhold recalls "....an extremely hectic and stimulating period in my life and one which helped me to come to grips again with some of the fundamental ideas in physics."[10] The trials teachers had to work very hard to become familiar with the new materials and equipment, to attempt changes in teaching style and to attend many meetings in the school, at regional level and at the important briefing conferences in Birmingham.

At school level the meetings at Huddersfield New College involved planning for three NAP groups, all being taught simultaneously but all at different points in the course. Consequently, some of the teaching was ahead of many schools. This scheme allowed the flexibility of the NAP course to be tested to see if there were any disadvantages in starting at different points. The regional meetings, organised by Bryan Chapman in this instance, were helpful in exchanging views and in answering particular problems about the course detail and, of course, in comparing progress.

By the end of the first term of the first trials it was rapidly becoming apparent that the schools were varying widely in the time taken to teach the introductory material, and many teachers were worried that they had taken so long. In response, the December 1968 Newsletter contained a carefully worded letter from Jon Ogborn arguing that this state of affairs was inevitable with strange material and the tendency on the part of the team to over-burden the course: "It is very likely that in writing the course we have been tempted to make too many experiments into individual pupil experiments."[11] Ogborn recommended that teachers try to be flexible in their use of the teachers' guides and assisted by suggesting examples of work that could be re-arranged or omitted. Clearly, the Joint Organizers were worried that the trials teachers would revert to didactic teaching and demonstrations, in order to cover the materials, and they made a plea for teachers to do demonstrations *with* the class rather than *to* the class, i.e. the class should help with the experiment and the discussion to create lively and active sessions.[12]

Finally, the briefing conferences of all the trials teachers were particularly important for discussions about the radical physics included in the NAP course and to experience prototypes of newly developed apparatus, particularly in electronics (Unit 6). Overall, then, Archenhold felt that the major aims of NAP resonated with his own views about teaching and that his guarded enthusiasm transmitted itself through to his colleagues, and that this resulted in a very positive response from the pupils.[13] He would write later:

> "What is self-evident is that learning for understanding requires the active participation of the student. It demands a high degree of commitment to meet the challenge of grappling with new ideas and problems, and requires initiative and perseverance. Last, but not least, it requires hard work."[14]

If the teachers found NAP trials demanding, the trials pupils were also exposed to additional tensions and not all were able to respond positively. In another trials school Wenham observed: "There is undoubtedly tension with some of the boys but, interestingly enough, the major anti-Nuffield protagonists have now abandoned the Science Sixth and gone to Economics. All were boarders and this may have some significance since there is a deal of unspoken disapproval of the Nuffield development [NAP] in the school (by, to some extent, it is thought, the Head and more openly by the master-in-charge of examination entries)....You [Ogborn] may know that the "better" set is doing traditional A-level. But, thanks be, they did a very bad mock exam - and showed up badly in comparison with their Nuffield fellows."[15]

The question of examination grades and university entrance requirements is never far from the surface in A-level curriculum renewal. For instance, the only published response to Black and Ogborn's general article on NAP in 1970 was from A.S.Wiltshire, who asked: "....what arrangements have been made to protect the interests of the guinea pigs [the trials pupils] during the experimental phase of the scheme? The Nuffield students must be at a disadvantage compared to their conventional competitors."[16] Fortunately, Paul Black had the data from the first NAP examination, as well as the experiences from the other Nuffield A-level Science examinations, to point out that trials candidates produce standards of performance appreciably higher than in traditional examinations. He cited several reasons: "....trials teachers have to put much more effort into teaching a new course, students do seem to respond positively to the trials situation, there is a much closer rapport between examiners and teachers about the objectives of the examination and, finally, there is the possibility that the course leads to more effective teaching."[17]

Whatever solicitude the Joint Organizers may have felt during the first trials they soon pressed on with their plans for the second cohort of trials, planned to start in September 1969. They selected a further thirty-one schools and two FE Colleges to trial the second draft course materials: "We were then trying to broaden the net and to make sure that we had tried the course under a good range of possible circumstances. We weren't especially anxious to try it under extremely unfavourable circumstances so a new trials school would need to be willing, and we wanted the physics teachers to be willing, not just the Head. We also wanted schools that we believed could manage and then, within that, as wide a spread of schools as possible."[18] Following the lead from NAB, four schools were included from Northern Ireland and were visited by Jon Ogborn and Bob Fairbrother. It was in the Province that Ogborn remembers the only school to reject NAP trials status, where the Headmaster firmly believed that his pupils' examination results would suffer, despite well documented evidence to the contrary.[19]

The slightly notional inclusion of the two FE Colleges realized another of Long's aspirations for the NAP project, namely to include some element of the physics taught in technical education into the trials phase . The then Statistics Officer for the Associated Examining Board (AEB), J. Wilmut, calculated that about 25% of the overall A-level Physics examination entry came from FE Colleges. [20] Consequently, Bill Bolton, on secondment to the NFSTP from an FE College, approached Highbury Technical College, Portsmouth, and East Berkshire College of Further Education, Windsor, to assist in the NAP trials.

Simon Pascoe, at Highbury, volunteered to teach some of the NAP Units. He had been teaching the traditional AEB Physics syllabus for five years and had found the NAP materials to be interesting and different: "I liked the idea of doing something different and having a course where some of the experimental work was in class sets. Everyone did the same experiment in half an hour, or twenty minutes, and then discussions tried to draw all the strands together. The approach seemed to be so much better than traditional, separate practicals."[21] Pascoe's main impression was that he enjoyed teaching the trials materials even though it involved a lot of extra work getting used to the novel equipment and ideas. He felt that he needed to organize the practical work carefully, to make sure that the students could cope, and that he had to make sure beforehand that he was familiar with all the materials and equipment: "I wanted to master all the things I did before going into the classroom particularly the numerical analysis work in Units 4 and 5. Some of this work was very new to me and required a lot of preparation in the evenings. It wasn't that the work was difficult, just that it was different."[22]

Before teaching at Highbury, Pascoe had been employed by Marconi, the electronics company, so he took responsibility for teaching the innovative work in Unit 6: *Electronics and reactive circuits*: "I liked Unit 6 because it taught me some electronics and I understood a number of things for the first time. The students responded well because it was activity based and they liked the idea of building up systems from the basic units. Some students who were not very good at other parts of the NAP course suddenly took to Unit 6."[23] Much of the equipment for Unit 6 was constructed in the college by the 'excellent laboratory technicians' and there were no delays in obtaining the new equipment needed to teach the course.

A number of meetings were arranged between the trials teachers in the two FE Colleges to help exchange ideas and experiences. Peter Drake, at East Berkshire College also found the NAP trials hard work but was able to identify considerable benefits for his own teaching: "Looking back over the two years of teaching the Nuffield A-level physics course, the greatest impression is of how my style of teaching has changed; the syllabus is very different, but it is the classroom situation that has required the greatest adjustment on my part. I still lecture sometimes, but very seldom for a whole lesson, and my usual place in the classroom is now sitting at the table with the students discussing a demonstration, rather than standing in front of a blackboard. Occasionally, I find it necessary to give notes, in the conventional way, but usually only to summarise after preliminary demonstrations. For a teacher new to the course, I think it is this adjustment to the new role that gives difficulty (and for the students as well, of course)".[24]

Drake's colleague, Mike Alsop, was less enthusiastic about NAP and felt that the college would need to offer a traditional course to parallel NAP. Alsop was concerned at the reduced content and echoed the fears expressed by Chambers and Allanson : "I [Alsop] would argue that before we can understand Physics, we need a store of information on which to call, and I wonder what the difference is between the stored information of a Nuffield student and that of a Traditional student."[25] Alsop hoped that a gradual compromise could be reached where traditional courses become 'Nuffieldised' and that even the NAP style of teaching could be applied to traditional syllabuses. Overall, Alsop welcomed the NAP trials and the resultant change in attitudes of both students and teachers:

"I am certain that if nothing else it [NAP] has taught me to look more closely at what I am teaching and how I am doing it, and not least why I am doing it."[26]

In the summer of 1970, during the NAP trials, Pascoe, Alsop and Drake attended an FE conference in Huddersfield, comparing the Ordinary National Diploma (now BTEC) with existing A-level courses. As NAP trials teachers they were asked to demonstrate parts of the course and display the novel Nuffield apparatus. So, well before the publication in 1972 some form of informal NAP diffusion was taking place - diffusion referring to the spread of curriculum materials, ideas, values, attitudes and behaviour.

After publication of all the Nuffield A-level Science projects Peter Kelly, Jan Harding and Robert Nicodemus set up the Curriculum Diffusion Research Project, based at Chelsea College and primarily concerned with the diffusion of the NFSTP innovations. They used a multi-dimensional research pattern of six complementary studies to overview the diffusion process:

- the planned dissemination programmes of the projects;
- diffusion over time based on examination entries;
- questionnaire surveys of schools on a national scale;
- study of LEA communication and support systems;
- school based case studies;
- exploration of diffusion data from HMI, project teams etc. [27]

The universal reaction is one of complexity and difficulty in formulating generalised explanations of diffusion. However, the project did establish a terminology which will be used in further discussions about the diffusion of NAP. Dissemination refers to the conscious process in which the project materials and ideas are spread beyond those involved in the development.[28] Kelly et al categorized the NFSTP dissemination aims as follows:

- *Adoptive aims*, in which teachers will adopt an innovation and implement it faithfully.
- *Adaptive aims*, where teachers adapt some aspect of an innovation to their current practice.

- *Innovative aims*, whereby the dissemination will stimulate further innovation and foster the professional development of the teacher.

- *Instrumental aims*, which indirectly encourage adoption, adaption and innovation to, say, examinations, text books and syllabuses.[29]

In the first instance, Black and Ogborn did not have time to establish a dissemination plan for NAP and did not formalize such dissemination aims. However, by the end of 1970 'area centres' had been established, mostly based in university departments, and these centres formed the structure for NAP's dissemination plans at publication.

Area	***Organizer***	***Institution***
North East	W.F.Archenhold	University of Leeds
North West	C.Varley	Hillfoot Hey High School, Liverpool.
Leeds	B.Chapman	University of Leeds.
West Midlands	E.J.Wenham	Worcester College of Education.
Midlands	G.Foxcroft,and B.Taylor	Rugby School.
Home Counties	A.W.Trotter	Chelsea College.
	R.Fairbrother	University of London.
East Anglia	I.Morrison	Homerton College, Cambridge.
South Wales and Bristol	J.G.Jones	University College of South Wales
Northern Ireland	H.McKeown, HMI	HMI
Oxford, Berks and Bucks	B.Hann	Clarendon Laboratory, Oxford.
F.E.Colleges in London area	P.Lawton	Garnett College of Education.

The NFSTP provided extra funds to enable Jon Ogborn to continue to organize NAP for one more year after its allotted project time expired in

September 1971, and to assist in implementing the dissemination plan. The NAP Organizers devised a classic plan of training the trainers, spearheading, in which a systematic series of in-service courses [INSET] were arranged at the area centres and led by NAP team members. The courses were designed to overlap, so the team members 'lived out of suitcases for about three months' as they travelled throughout the country. After this initial input the area centres were encouraged to introduce in-service NAP courses, and other centres, such as Bristol University and Kingston Polytechnic, ran courses for a number of years.[30] From the inception, the University of Leeds has organized NAP courses yearly since 1972 (in 1990 there were too few applicants) until the present day. Bryan Chapman and Fred Archenhold extended their trials schools co-ordination role to organize NAP (and Revised NAP) in-service courses, so that in the late 1980s and 1990s this was the only INSET course on offer.

The availability of all the NAP materials during 1972-73 and the establishment of a national network of in-service courses placed many physics teachers, LEA Science Advisors and educational administrators in a difficult position. Decisions had to be made to take up the new A-level materials to a greater or lesser extent, to continue with their current syllabus and adopt a 'wait and see' policy, or to reject the new ideas completely.[31] Tebbutt identified this situation as the first of possibly two critical stages in the dissemination of NAP. A second stage occurs much later when the course has been used for some time and perhaps has been found wanting: "At this stage the [NAP] teachers may decide to continue with the course, or they may change to another course either because the original course is out of date or because rival courses have appeared which have greater appeal, or few demands."[32]

For the first stage, Ingle and Jennings have recognized four main groups of sources that cover the degree of take-up of many curriculum projects, including NAP:

1. the study of examination entries;
2. the research of the Curriculum Diffusion Research Project;
3. surveys conducted by HMI, and other researchers;
4. the Schools Council enquiry into the impact and take-up of curriculum projects.[33]

Communications for these studies (2,3,4) were with a wide variety of people involved directly, or indirectly, with the curriculum projects: physics teachers, Heads of Science, Headmasters, HMI, LEA Advisors. In the case of the Nuffield O-level projects a considerable time had elapsed between the projects' publication and the research, but this was not the case for the A-level projects. Not surprisingly, a wide range of use is reported: Table 5, page 113, lists a range of adoption[34] and Table 6, page 124, focusses on the Nuffield A-level projects.[35] Walker reasons that as "....the Nuffield Science project/publications became more familiar to teachers, 'Nuffield' and 'non-Nuffield' classes became more and more difficult to distinguish and the categories more and more blurred..."[36]

Focussing on the discrepancies in Nuffield A-level science adoption illustrated by the Curriculum Diffusion Research Project(2) on one hand, and HMI and Schools Council(3 and 4) surveys on the other hand, Nicodemus suggests that a possible reason for the high adoption in NAP, and particularly NAC, could be due to active communication from quite different sources:

> "In the Chelsea project [Curriculum Diffusion Research Project], high adopters of A-level Chemistry [NAC] had a significantly higher frequency of contact with trial schools. However, for Nuffield O-level and A-level Physics high adopters had a greater variety of frequent contacts, both personal and printed, e.g. staff from other higher education institutions, Schools Council publications, ASE publications, meetings of specialist subject associations, meetings organized by the DES."[37]

These suggestions for NAP are consistent with comments given in interviews for this work, from both the development team and NAP teachers.

In order to draw realistic conclusions, Ingle and Jennings[38], and Tebbutt[39], believe that the use of examination entries (1) supplement the diffusion information from other sources (2,3,4) to give a fair estimate of the take-up of a curriculum development. An exemplary study by Crellin, Orton and Tawney analyses O- and A-level Physics syllabuses including the special examination papers set for the Nuffield courses. They are quick to point out that: "Only a minority of students take these Nuffield examinations: in the summer of 1977, 10 years after the course was published, 18% of the candidates took the Nuffield examination at O-level; in the same summer, 6 years after the course was published, 16% of candidates took the examination at A-level. (Nevertheless, this means that more candidates now take this examination than any other physics examination at this level.)

Table 6. Uptake of NFSTP in Secondary Schools 1968-78 - publication dates in brackets-
(after Tall (1981))

Source	**Schools Council (1969)**	**Nicodemus (1975)**	**Booth (1975)**		**Bradley (1976)**				**Schools Council (1980)**
Year	1968	1973	1973		1976				1978
Sample	120 LEAs	157 Heads	1 732 Heads		174 Heads				396 Schools
Response rate	74%	75%	100%		65%				63%
	Uptake	Uptake	Doing	Uptake	Occas-ional ideas	Subst-antial use	Total use	Extent of uptake	School use
Nuffield O-level									
Biology (1966)	34	48	9.7	57.8	45	17	3	65	71
Chemistry (1966)	34	48	11.7	59.1	35	20	10	65	69
Physics (1967)	37	48	13.0	60.7	47	11	6	64	70
Nuffield A-level									
Biology (1970)		13	10.5	31.8	47	5	9	62	53
Chemistry (1971)		18	19.1	45.3	30	16	24	60	62
Physics (1971)		13	13.8	28.3	44	3	11	58	47
Physical Science (1973)		-	1.7	2.9	8	0	0	8	18

Table 7. Uptake of the Four Nuffield A-level Projects - from *Aspects of Secondary Education*, HMI, HMSO, 1979: Annex to Chapter 8 p205. *Percentage of the 205 schools with sixth forms who replied to survey* (total response rate was 85%)

Doing = the project material constituted the actual course
Substantial use = the project material was used but the course itself was not the project course
Some use = some project material was used but only to a minor extent

	Extent of Use			**Little/No use**
	Doing	Substantial use	Some use	
Nuffield A- level				
Biology	8	5	27	06
Chemistry	17	17	21	45
Physics	12	4	22	62
Physical Sciences	2	1	2	95

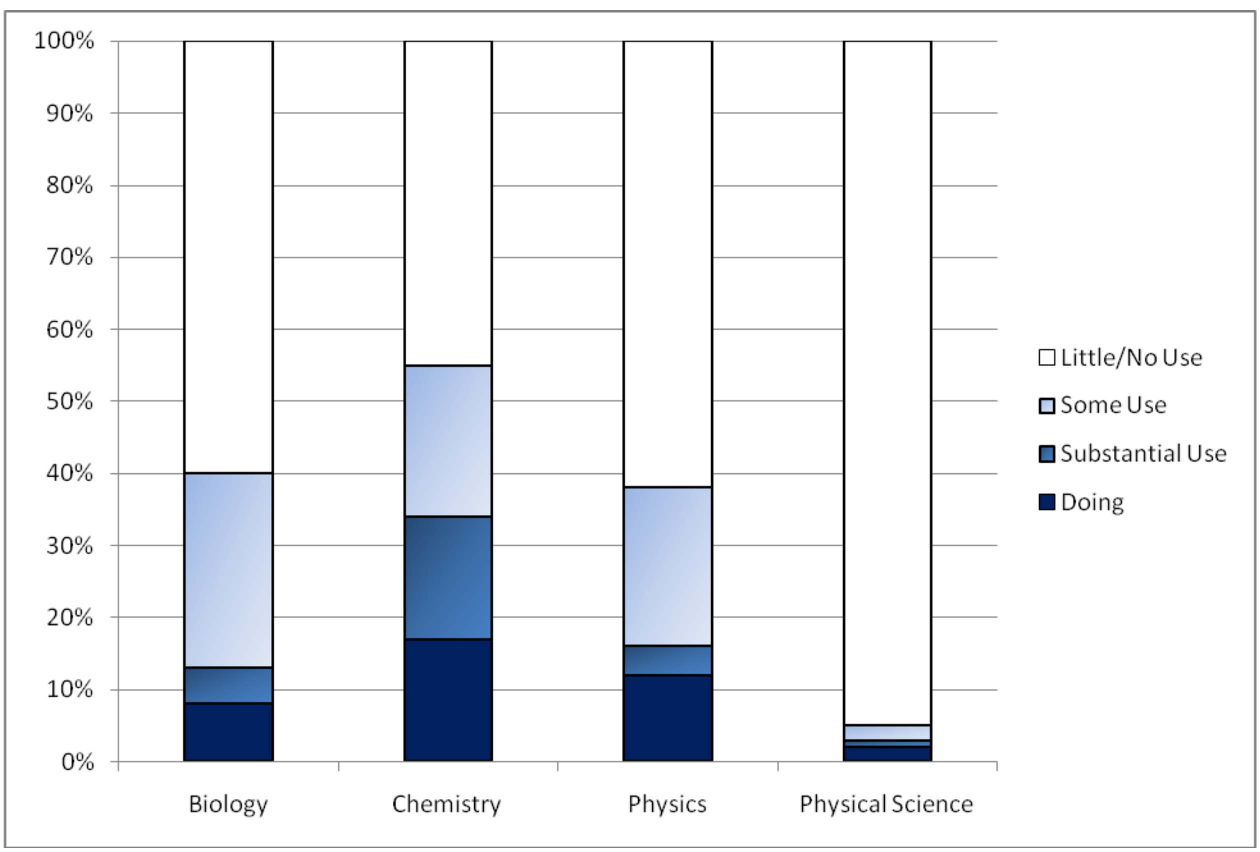
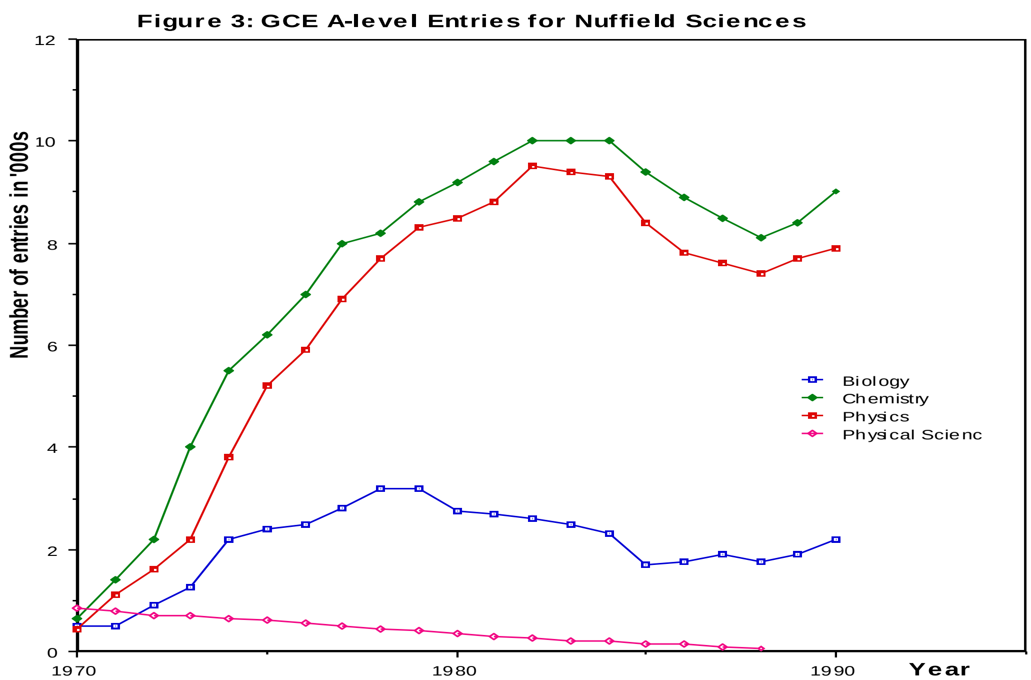


Table 8. Nuffield A-level Physics Entries and as a percentage of all A-level Physics Entries by Year

Year	Nuffield Physics Entry*	All Physics Entries**	% Nuffield
1970	447	42 243	1.0
1971	1 091	41 776	2.6
1972	1 0560	40 112	3.9
1973	2 169	38 892	5.6
1974	3 829	39 806	9.6
1975	5 158	37 168	13.9
1976	5 915	37 119	15.9
1977	6 897	40 567	17.0
1978	7 708	40 821	18.9
1979	8 8301	43 491	19.1
1980	8 453	45 158	18.7
1981	8 844	47 051	18.8
1982	9 485	49 794	19.0
1983	9 403	49 782	18.9
1984	9 279	49 000	18.9
1985	8 426	46 606	18.1
1986	7 805	43 563	17.9
1987	7 595	42 003	18.1
1988	7 417	39 183	18.9
1989	7 707	38 672	19.9

*NAP entries supplied by Mrs B.G. Fraser, Oxford and Cambridge Schools Examination Board
**All A-level Physics entries supplied by the Associated Examination Board



The influence of the courses is estimated to be wider, approximately 50% of schools claiming to use Nuffield materials and ideas."[40] Eventually, the NOP entry rose to about 20% of the total and the NAP entry to about 19% of the total entry .

But information supplied by the Secretaries of the Examinations Boards does not support the last claim made by Crellin et al. The extract below clearly shows that NAP was not, and is not, the largest A-level Physics examination. However, these figures include overseas entries, and NAP is one of the largest A-level Physics examinations for students in England and Wales.

A-LEVEL PHYSICS EXAMINATION ENTRIES (Selected Boards)

	1972	1982	1989
JMB	10,984	13,981	11,500
LONDON	10,624	11,925	9,704
AEB	2,500	7,413	6,976
NAP	1,560	9,485	7,707
TOTAL (All Boards)	40,112	49,794	38,672

For convenience the A-level entries for 1970-1990 have been put into graphical form and a comparison can be made with the other Nuffield A-level Science examination entries (see Figure 3, page 126).

When examining the growth of NAP due care must be exercised in considering the entries from the trials schools. These candidates, of course, are determined by the project itself and not the variety of other factors which influence diffusion. Tebbutt[41] estimated the following NAP entries for trials and non-trials schools:

	1970	1971	1972	1973	1974	1975
Trials Schools	447	867	1118	1103	1185	1122
Non-Trials	-	228	451	1076	2656	4036

Ogborn offers another consideration:

> "In some respects our anxiety was to stop it [NAP] growing too fast, because how would we cope with the examination arrangements? The whole examination business was growing at about as fast as we could manage it; having to recruit examiners and train them. I remember being asked, "Were we worried it [NAP] wasn't growing

faster?", and saying in public that I was glad it was not because the whole examination might crash."[42]

In attempting to extrapolate further the growth of curriculum projects Tebbutt has concluded that the Nuffield O-level projects grew as a result of contact between teachers. The Nuffield A-level projects, however, were unlikely to grow by diffusion processes, at least not to the same extent, since there was a tendency for schools to continue with the equivalent A-level project, having adopted the O-level project.[43] During this early growth stage the NAP team did not discuss, in depth, the expected take-up of the examination. The Organizers had closely observed the growth in NOP and therefore expected a similar response for NAP.[44]

The Nuffield A-level Physics course and examination were set up in a distinctive, revolutionary way, using gifted physics teachers from schools and universities to select, in their opinion, a coherent course content, innovatory apparatus, an individualistic teaching and learning pedagogy and an examination including a variety of assessment techniques. With hindsight, it is not surprising, then, that a majority of physics teachers did not enter their students for the NAP examination, and many (about 50%) did not consciously use NAP materials and ideas. Fred Archenhold met many such teachers at NAP dissemination courses held at Leeds during the 1970's:

"Quite a number of teachers argued that they preferred what they regarded as a less revolutionary syllabus change, as offered by the GCE Boards, as opposed to going all the way with Nuffield [NAP]."[45]

So, many of these non-adopters were soon exposed to parts of the NAP revolution through the gradual changes to examination syllabuses and also to the wide acceptance of NAP experiments and apparatus. Of course, these teachers would be more dependent on the use of text books. Here, too, many NAP experiments, examination questions and course ideas soon appeared in popular A-level physics text-books, written by Duncan, Bolton and Wenham et al, which were published soon after the NAP project. The influence of NAP is acknowledged by these authors. However, there was still a demand at the more traditional end of the market, where the influence of NAP was less pronounced, for reprints of books by authors such as Nelkon, Whelan and Hodgson.[46]

An HMI survey carried out in 1979 concluded:

"A major result of Nuffield course development [including NAP] has been through the thorough and wide-ranging review and changes made by examinations boards in recent years to syllabuses and to style of questions and question papers. Most would agree that these have been beneficial to science teaching. In general, the projects have had a great influence on the introduction of practical work in science courses of all kinds, not just those labelled 'Nuffield'."[47]

An early instrumental aim of the NFSTP was to generate changes in traditional O- and A-level examinations. In Tall's view, the Nuffield A-level projects created an even greater break with tradition, by introducing teacher-assessed project work and individual investigations.[48] The NFSTP were well aware that the NAP examination, itself, would be the agent most likely to influence teaching methods and perhaps even teaching styles.[49] An indication of the general response by the GCE Boards to curriculum development projects such as NAP is provided by Michael Kingdon, then Head of Research at the University of London School Examinations Board:

> "Quite quickly the examination boards' syllabuses came to adopt the more worth-while and interesting parts of the innovations associated with the [curriculum development] project."[50]

Extensive research into A-level physics syllabuses by Crellin, Orton and Tawney has highlighted some of the important differences and the initial changes, made by the GCE Boards:

- the move to give a substantial percentage of marks for the higher abilities of Application, Evaluation and Investigation, and less for straightforward Knowledge;
- the inclusion of Comprehension and Short Answer papers;
- changes to the style of questions (the NAP questions are more searching and less straightforward and encourage students to attempt a novel problem as a physicist would, rather than reproduce accurate descriptions of standard experiments and derivatives);
- to include an applied approach to electronics and, overall, to increase the weighting to Application;
- to include 'theory' questions with a practical bias;
- to reduce 'mathematical handle-turning' in Physics questions;
- the use of a Formulae and Relationship Sheet in the examination;
- to reduce excessive choice in examination papers;
- to extend the examination profile and range of question types;
- to introduce changes to the assessment of practical work and to increase the allocation of marks for practical investigations;

- to reduce syllabus content. [51]

In the case of the London Board's A-level Physics syllabus all these changes can be observed but only over a twenty-year span, 1972-92. The earliest London A-level Physics syllabus was published in 1952 as two closely typed pages of topics under headings similar to the later Gulbenkian proposals : General Properties of Solids, Liquids and Gases; Heat; Sound, Light; Magnetism and Electricity, Practical Examination. By 1972 the syllabus statement had grown to four and a half pages but was still grouped under the familiar traditional headings (see syllabus comparison at the end of Chapter 3). Perhaps in response to NAP, a major revision was published in 1973, using for the first time terms such as Knowledge and Understanding, and relating concepts to practical work. These changes were accompanied by an enlarged examination profile similar in form to NAP. This syllabus, which lasted with minor modifications until the early 1980s, appears to be overloaded, and evidence is found in Ridley's analysis below (see pages 133-134).

In such situations, syllabus developers are placed in a difficult position. There is the full weight of tradition in the old syllabus to accommodate, plus the desire, and pressure, to include new material. This conflict was felt keenly when revising the NAP course during 1982-84 . On the other hand, Black and Ogborn were able to start with a clean slate and, to their credit, produce a 'lean and tough' A-level course. Finally, in 1992, the London A-level Physics syllabus entry has thirty pages of introduction, syllabus and notes, with the physics grouped in broad themes: Physical Quantities, Mechanics, Energetics, Matter, Field Phenomena, Wave Phenomena, Experimental Physics, plus a choice of two from five Topics emphasising applications in physics, and inspite of the increase in pages the syllabus content is much reduced.

In some topics there has been a complete adoption of NAP ideas, in, for example, the systems approach to electronics advocated in Unit 6. However, the gradual changes implemented by the Examining Boards during the twenty years have made it easier for NAP teachers to change to other syllabuses, and vice versa. This was apparent after the revision of NAP and may continue as a result of subsequent changes made to the RNAP examination structure . When curriculum projects reach Tebbutt's 'stage two' they are particularly vulnerable to changes by teachers to other syllabuses. A study of NAP examination entries reveals a sharp drop in candidates at the revision stage, which may be attributed to syllabus changing.

In reviewing the interaction between curriculum development projects and their project examinations, and the work of the GCE Examining Boards, Kingdon goes on to say that:

> "When special project examinations are established, however, this served in some cases to preserve the identity of the project. The existence of such an examination can also in some ways fossilise the project. Examination board syllabuses, with their two to three year cycle of development and improvement, could quickly absorb new ideas and consolidate them. The project with their associated books, films tapes and other material could not change as quickly without quite unreasonable degrees of investment by the schools."[52]

Nevertheless, the *innovative* and *instrumental* aims carried forward by Black and Ogborn continued to keep NAP up-to-date, both in the structure of the examination and in the revision of the course materials, which incidentally were never intended to form the examination 'syllabus'.

Kingdon's colleague at the London Board, Alan Stephenson, has recorded the impact of the NFSTP developments, and the pressures which they, in turn, have created for for Examining Boards:

> "Most examining boards have modified their science syllabuses in the light of Nuffield projects and in consultation with teachers, but with the tremendous effort and consequent strain on resources required to formulate new courses and examinations in a wide range of subjects (30-40) in a limited period of time, I think the examining boards are unlikely to give priority to the development of 'pure' Nuffield courses and examinations."[53]

Examining Boards have to look continually at courses and examinations over a wide front and the financial resources are not available to initiate curriculum reform on the scale carried out by the NFSTP. Therefore, there is still a need for curriculum projects on a national scale, developed in close conjunction with the Examining Boards. A notable feature of the Nuffield A-level projects is the mutual respect created between the Nuffield-Chelsea Curriculum Trust (NCCT), previously the NFSTP, and the

Examining Boards and, in turn, the continuous cooperation received from the parent Board.

In organizing this history of NAP it has become apparent that some university teachers have, at times, exercised considerable scepticism about the course, and physics teachers considering adopting NAP are rightly concerned about their students' future. This concern has prompted Crellin et al to conclude that "....although the Nuffield A-level physics course is proving very popular, many distrust the move towards higher abilities (Application, Evaluation and Investigation), fearing that it will make physics even harder than it is already. There is also some doubt whether tertiary education institutions really want entrants who have developed their higher abilities, perhaps at the expense of knowledge."[54]

A particular example of university recalcitrance occurred in Northern Ireland. Professor H.B. Gilbody, Professor of Physics at the Queen's University of Belfast, was initially hostile towards the NAP course and particularly towards the mismatch in content with his Entrance Scholarship examination papers. This was particularly awkward for the four Northern Ireland NAP trials schools. A lively correspondence ensued between the NFSTP, HMI, Professor Gilbody and the Vice-Chancellor of The Queen's University, until finally it was agreed to alter future papers, to ensure that NAP students were able to answer at least the prescribed minimum number of questions. A similar agreement was eventually eked out from the Universities of Oxford and Cambridge. Moreover, in his reply to Keohane, Gilbody itemized his concern:

> "As you know my earlier correspondence with Dr.Black was concerned primarily with the suitability of our Entrance Scholarship Examination for Nuffield candidates. However, the more important question which we have had to consider is whether, for the purposes of University entry, we can regard Nuffield A-level pass grades as equivalent to the pass grades of the standard A-level examinations. Although we feel that many features of the Nuffield courses have considerable merit, we are seriously concerned by the large number of important basic topics not covered by this course. We therefore feel that, on entry to the University, a Nuffield candidate could be at a serious disadvantage compared with a student who had covered a large fraction of, if not all, the standard A-level syllabus. Of course it may turn out that these fears are unjustified since it is possible that

the Nuffield student's training would enable him to cope more effectively with the more advanced University courses."[55]

In his 1979 survey of NAP teachers, Tebbutt also found that some school physics departments were aware that reports from former NAP pupils, and some admissions tutors, implied that NAP was not favourably regarded in universities and, as a result, the schools had decided to run parallel NAP and traditional A-level sets.[56] These 'rumours' contradict Head's conclusions based on his extensive inquiry into university tutors and former Nuffield A-level pupils, in which the enthusiasm and interest of the Nuffield students were praised. Some criticism was levelled at omissions in knowledge, however. Significantly, one criticism often made of the first Nuffield O-level schemes was not made of the A-level courses: that the concepts were too difficult and the content too large.[57] In 1980, Paul Black decided to resolve this issue and conducted an extensive survey of Higher Education departments with an interest in physics and found conclusively that the great majority did not discriminate against NAP students.

Michael Ridley was confronted with the 'rumour' when he was appointed, in 1979, as Head of Physics at the John F.Kennedy Comprehensive School in Hemel Hempstead. After his first year Ridley decided that he wanted to adopt the NAP course and examination:

"I liked NAP from the word go. There was ample opportunity for a lot of dialogue between the teacher and the students. At the time I liked the idea of the 'little red books' [Students' books] and found that they covered the whole of the course if you went through virtually every question. I also liked the idea that virtually everything that was to be taught was done through some sort of demonstration or experiment, or other visual way of presenting it. So you effectively did not have a distinction between theory and practicals."[58]

At the time, Ridley's school was using the London Board Physics A-level and even though he used NAP experiments and teaching styles this did not fit into the school's tradition of theory lessons and a circus of unrelated practical exercises: "I considered several ways of developing the existing 'traditional' A-level physics course in this school; in particular, I was seeking ways in which the course could be made more divergent, less rigidly split into theory and and practical and could involve more examples from so-called 'Modern Physics'. Having previously taught NAP at another school [Grove Hill Comprehensive School, Hemel Hempstead], I could see that Nuffield could fulfil these aims, but there did seem to be some disadvantages about the scheme. One of these was that the course content appeared to be less than in the traditional syllabuses, and this could handicap some pupils when taking higher education courses, as their basic knowledge would be restricted."[59]

Under the influence of 'rumour', Ridley wrote to a majority of university physics departments seeking their views about NAP students and he published the results of his questionnaire in the School Science Review. The overriding impression, once again, was that NAP students were not treated differently and that only one department (out of 33 replies) definitely asked for higher grades from NAP candidates. Encouraged by the results of his initiative, Ridley continued his negotiations with the Hertfordshire LEA Science Advisors, hoping for a special grant to introduce NAP. In reply, the Advisors voiced their support generally for NAP and provided a small grant of about £1000. This grant was not sufficient to purchase the full recommended range of NAP equipment . But Ridley was working with small groups of A-level students and, together with his experience of NAP, this enabled him to eliminate those experiments that he felt were not quite so successful and to reduce the quantity of equipment in some areas.

As an aside, Ridley did not continue with NAP after its revision in 1985. Even though his students liked NAP some of his borderline candidates found it difficult to complete the course and he concluded that NAP was more suitable for the more able students: "We perceived that NAP was not quite so good for the borderline candidate who really wants to know what he is supposed to know and then go away and learn the physics, and then pass the examination. At the end of the day, whatever ideals you have about good education, you also want the students to get value for money - taxpayers' money."[60] So the question came to a head when the NAP revision was published, because of the extra expense needed for books and equipment. Furthermore, the school decided that in order to accommodate the needs of a wide ability range, it would be best to change back to the revised London Board A-level, which Ridley felt had now taken on board many of the ideas of the original NAP scheme. In fact, he carried out his own syllabus analysis of the two revised course and felt that the new London A-level now had less content than the enlarged Revised Nuffield A-level Physics (RNAP) course.

One subject that is paramount in the adoption and adaption of schemes such as NAP is the role that finance plays in the decision making.

There is a general consensus of opinion, in the literature, that lack of money is the principal factor in deciding to adopt the Nuffield schemes. Gould places 'high costs and demands on teaching resources' first on his list of factors limiting adoption,[61] and Tall is emphatic:

> "If a greater level of finance had been available, or the projects had been cheaper, adoption would have occurred faster and may well have reached higher levels."[62]

It is clear from earlier discussions indicating that the Nuffield A-level projects grow, in part, from extending the O-level projects into the sixth form, that the influence of finance on the diffusion of NAP requires some discussion about the initial expenditure on NOP. At the same time, it is important to look at the response of the LEAs to such curriculum innovations. The analysis of NAP examination entries by each GCE Board, shown below, indicates clearly that about 80% of schools entered for the NAP examination come from the state sector, representing about 75% of the total NAP entry, and are therefore subject to the financial directives of their LEA. The data were synthesized by the time-consuming analysis of 1984 examination entries for each NAP school.

TABLE 9

NAP EXAMINATION ENTRIES FOR 1984 FOR EACH GCE BOARD

	SCHOOLS		CANDIDATES	
	Independent	State	Independent	State
O and C	54	12	1767	186
UCLES	12	94	296	1540
LONDON	13	97	212	1584
JMB	3	42	95	1798
OXFORD	3	61	55	1192
AEB	0	46	0	573
WJEC	1	4	11	129
TOTAL	86	356	2436	7002
% of TOTAL	19%	81%	26%	74%

Key:

O and C: The Oxford and Cambridge Schools Examination Board.
UCLES: The University of Cambridge Local Examinations Syndicate.
LONDON: The University of London School Examinations Board.

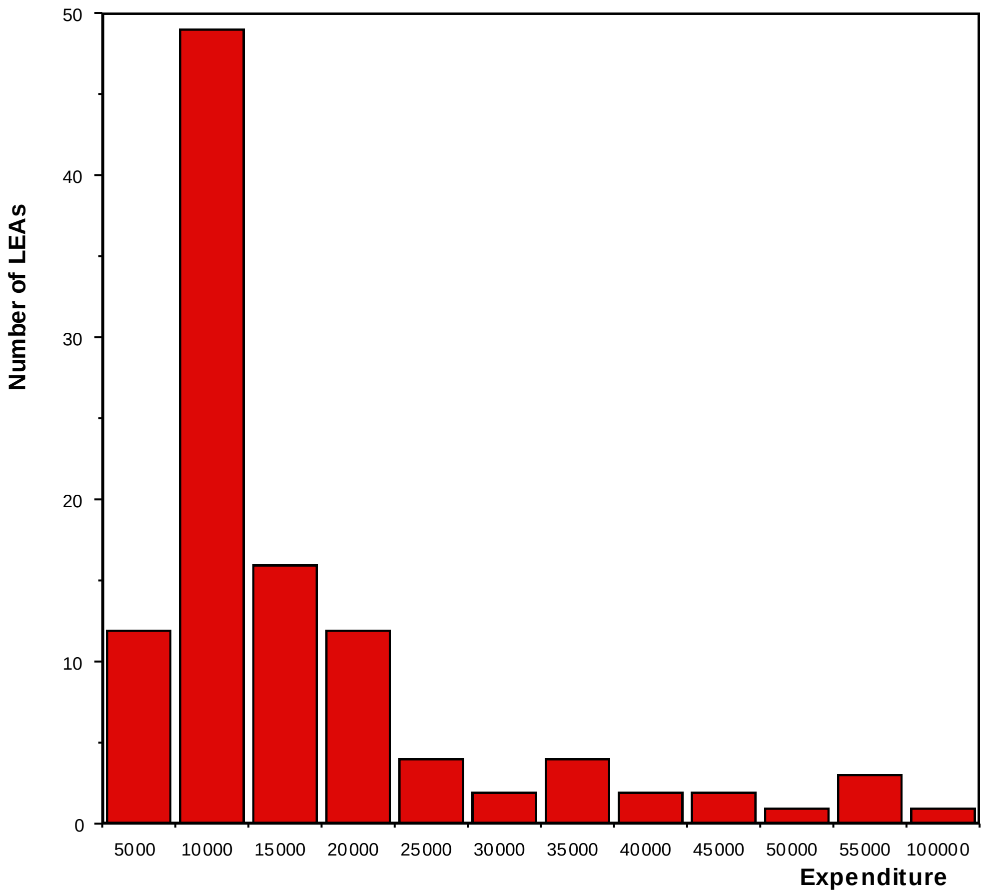
JMB. : The Joint Matriculation Board.
OXFORD: The Oxford Delegacy of Local Examinations.
AEB : The Associated Examining Board.
WJEC: The Welsh Joint Education Committee. [63]

The NFSTP was acutely aware of the high cost of apparatus, especially in physics programmes: "Apparatus needed for the teaching of a single year of the physics programme [NOP] has often cost £750 or more....It is inevitable that these high costs should have raised the question of whether it may not be impossibly expensive for many schools to modernize their teaching of science in ways now thought to be desirable."[64] The initial NFSTP financial estimates, given below, clearly illustrate that expenditure on apparatus was the most significant outlay for the schools.[65]

NUFFIELD 'O' LEVEL PHYSICS (1967 prices, 5 year course, 32 in class)	£	**NUFFIELD 'A' LEVEL PHYSICS** (1971 prices, 2 year course, 16 in class)	£
Apparatus	3000	Apparatus	1500
Question Books	16	Students' Books	90
Teachers' Guides	4	Teachers' Guides	15
Experimental Guides	4	Reference Books	100
		Films & film loops	80
TOTAL(1967 prices)	£3024	TOTAL(1971 prices)	£1785

The good will of the LEAs was essential in this attempt to update school science curricula: "Finance is perhaps the major factor which determines the provision of apparatus....It is of course splendid that the authorities and their advisors should have responded so generously to the needs of the schools that have wished to adopt our [NFSTP] schemes."[66] Chillingworth recalls that the LEAs surprised the Nuffield Foundation in their enthusiasm and willingness to participate in school trials. He goes on to say that as the number of schools wanting to use NOP materials increased, authorities would be committed to a much larger capital outlay.[67] One year after the publication of the O-level projects, a Schools Council survey found that LEAs had spent in the region of £1.1 million on Nuffield equipment, with one authority alone spending £100,000, although most had invested much smaller sums:

Figure 4: LEA Expenditure - frequency distribution



(Taken from *Schools Council Survey*, 1969)

Harding offers further support to this wide-ranging response from LEAs. In one authority: "Physics teachers were already meeting [1967] to discuss changes in the curricula and had gained financial support from the LEA for new apparatus." Another LEA "....decided to spread the limited money available, to give modest sums annually to all who requested support and demonstrated use for it."[68] The Hampshire Education Committee, for example, resolved: "That, having regard to the need for encouraging scientific training in schools, the inclusion of £26,000 (for 36 schools) in the estimates for the financial year 1967/1968 in respect of Nuffield Foundation Science Teaching Project materials be approved in principle and that the matter be referred to the Finance Committee for consideration."[69] In the next financial year, Hampshire spent £41,500 in maintaining and expanding the NFSTP courses.

ESTIMATES FOR THE NFSTP 'O' LEVEL COURSES
(presented to the Hampshire Education Committee 5th July 1966)

	Physics	Chemistry	Biology
	£	£	£
Equipment	3000	350	931
Books	50	205	103
Film Loops	-	100	85
	3050	655	1119
Running costs for expendable material.	as now	£15 per lab per year	£100 per year

By this time, 1971, NAP was due to be introduced and the principle of a 'Nuffield Grant' had become a matter of course for the LEA, and this tacit acceptance by the LEA helped the NAP to become established in Hampshire. The then Hampshire Science Adviser, H.B.Lee, recalls that at this time Winchester College held some influence in the workings of the Education Committee and encouraged the availability of substantial finance for the NFSTP courses. For instance, in 1972 £57,000 was set aside to expand O-level and A-level schemes in Hampshire.[70]

Simon Pascoe, who worked for Hampshire LEA and helped trial the NAP course at Highbury Technical College, noted the high number of sixth forms in Hampshire (mostly in SixthForm and Tertiary Colleges) who offer

NAP. These institutions adopted NAP totally independently of their 'local trials school' and instead were heavily influenced by the intervention of finance allocated by the Hampshire Science Adviser.[71] For example, Peter Symonds' College in Winchester started the NAP course in 1976. The Head of Physics, Rod Parry, was influenced by the fact that NAB and NAC were already being taught in the College and that the chemistry course, in particular, was found to be successful. On a more pragmatic level, Parry felt it would be easier to administer the physics teaching to about 60 students by giving his experienced staff particular NAP units to deal with. This was also beneficial to the physics laboratory technician who would know immediately what equipment was needed for each teacher.

Parry sent detailed requirements and costings to the LEA Science Adviser based on equipment estimates for one class of 16 pupils:

NAP Unit	1	2	3	4	5	6	7	8	9	10	TOTAL
Cost of apparatus (1975-76)	£157	1125	214	583	136	235	232	56	42	4	£2784

Of course, one of the fundamental changes brought about by the Nuffield Physics courses was the listing of apparatus, which enabled LEAs to plan more effectively their apparatus provision for Nuffield and non-Nuffield schools alike.[72] Parry's Nuffield grant was made in two lump sums for the academic years 1975-76 and 1976-77, but money for Students' Books and other recommended reading material had to be found from within the school budget.[73] Since the early years, Peter Symonds' College had large NAP examination entries.

Harding, Kelly and Nicodemus' review of curriculum diffusion has recorded that LEA finances can have possibly two effects. Firstly, schools and colleges that accept LEA grants feel morally obliged to continue with the Nuffield work. Secondly, insufficient, or erratic, grants delay the start of courses such as NAP and often make its continuance uncertain.[74] Under these conditions some teachers may be reluctant to embark on the scheme, especially if they already have reservations about the educational merit of the materials, the style of teaching required, or the form of the final examination. In some cases, school reorganization from, say, a streamed grammar school into a comprehensive with a broadly based sixth form will generate uncertainty.

These twin issues of finance and teacher reluctance were aired in the March 1977 issue of *Physics Bulletin*, the monthly news journal of the Institute of Physics. A lively article by Ken Thomas noted:

> "Although there is wide agreement that we must endeavour to help pupils understand physics, rather than simply providing them with a set of facts, it seems questionable how many teachers are willing and/or able to do so. Apparently of the 40,000 pupils doing A-level physics, only 5-6,000 do it by the Nuffield route. How much of this is due merely to lack of money for facilities, and how much to teachers' reluctance?".[75]

Thomas' opinion was formed as a result of discussions at an Institute of Physics/ASE conference on *School Physics for the 1980s*. Of course, the Institute of Physics had been instrumental in getting the NFSTP started in the first place and many of the university physicists involved in both phases of NAP were Members and Fellows. Moreover, the Institute's approval for NAP came soon after publication in awarding the Bragg Medal and Prize to Black and Ogborn in 1973.

Overall, the science education literature contains few responses from physics teachers about the impact of NAP, perhaps because, as Tebbutt found, they were on the whole very satisfied with the course.[76] However, Thomas' article did elicit a rare published response from physics teachers, apparently from some who had not been able to start NAP. From E.C.Willis in Brampton, Cumbria:

> "Mr.Thomas seems to assume that the lack of worthwhile and well-tested innovations, such as the Nuffield A-level scheme, is due to teachers' inertia, but I am sure that a major factor is simply the lack of necessary funds or facilities....Even the welcome introduction of a limited number of Nuffield topics into the Joint Matriculation Board's new A-level syllabus is likely to cause financial embarrassment. The cost of a Hall probe, for example, is about £36 and an operational amplifier is listed at £16.50. One of each, which is a very modest provision for 20 students, will take half the money allocated to the whole of my physics department for apparatus for a year."[77]

A second letter from D.Williams detailed the capital expenditure needed to implement the Nuffield physics projects: "The capital expenditure to put it in to operation represented for many schools a sum far in excess of their normal budgets and where the money was available storage of equipment presented difficulties and in some case laboratories had to be rewired or even re-designed." Williams concluded that it was not surprising that schools were unable to adopt Nuffield physics, but ended optimistically: "All was not lost, however, because there was an important and very welcome spin-off in the form of new equipment. The anticipated demand was sufficient to interest several firms to produce their own versions of the various items at competitive prices. Consequently most schools use Nuffield apparatus even if they do not adopt the scheme."[78]

Inevitably, the gradual integration of NAP ideas into other syllabuses has guided and activated the physics equipment manufacturers. In the early 1980s Griffin and George Ltd., one of the main suppliers of NFSTP apparatus, no longer felt obliged to list Nuffield equipment separately in their catalogues because their customers no longer ordered full sets of NAP equipment. In addition, much of the original trials apparatus had been subsequently re-designed for a wider market acceptance and hence profitability.[79] The table below compares the costs over a ten-year interval, 1971 to 1981. The 1981 apparatus cost was calculated by adding up the individual prices for each item of NAP equipment, assuming a class size of 16 pupils. It is important to note, however, that, during those ten years, inflation was at a high level and retail prices, for example, rose by about 110% over the period.

ESTIMATED COSTS TO START UP THE TWO-YEAR NAP COURSE: A COMPARISON

	1971	1981
Apparatus	1500	7340
Students' Books	90	235
Teachers' Guides	15	25
Reference Books	100	300
Film and Film-Loops	80	90
	£1785	£7990

Although Parry, for one, clearly achieved value for money from the investment at Peter Symonds' College which has served large numbers year in year out, the cost to start up NAP from scratch, about £8000, became prohibitive. Ridley's approach to the problems (adapt experiments to avoid buying expensive equipment) seems sensible, but using cost implications in any decision to change an experiment (or course) may adversely affect the intentions of the innovation. So while costs cannot be ignored, great care must be exercised to ensure that cost and cost alone does not radically alter the nature of the physics being taught. This is particularly true when the work is intended to encourage initiative and enterprise amongst students of physics, a process which is heavily dependent on having appropriate apparatus and materials available.

Despite the inherent difficulties, Kerr found that most UK physics teachers support some form of an experimental approach, even when it is known to be expensive: "The British tradition of laying emphasis on individual practical work was strongly supported by teachers, though a minority (5%) warned against over-emphasis. There was a significant measure of agreement as to the values arising from practical work, but the extent of the agreement was much less for sixth forms than the rest of the school."[80] Kerr's seminal study, carried out in the early 1960s, helped inform the ASE and NFSTP emphasis on experimentally based science. The views propagated suggest that the value of such work lies in the involvement of personal discovery, in learning about 'being a physicist', in developing a sense of curiosity, and in learning skills for problem-solving and social group dynamics. In a later study, Thompson revealed that A-level physics students spent a considerable proportion of their time in practical activities, with NAP teachers in 'great disagreement' with their non-Nuffield colleagues in that they allocated rather more time to practical work.[81] Clearly, not all A-level physics teachers could accommodate the NAP styles of experimental work, and this provided yet another blockage to 'take-up'.

A number of studies in the science education literature have detailed the reasons for the active use of apparatus by students in their learning,[82] and some philosophical articles have also debated this devotion to experimental work.[83] However, Jon Ogborn's lecture, recorded in *The Role of the Laboratory in Physics Education*, edited by Jones and Lewis, summarizes this support for a student based, experimental approach to physics teaching:

> "Experimental work is costly in time and money, and its benefits are often hard to see. This is perhaps not best seen as a problem of 'efficiency', but rather as an inbuilt problem of teaching physics. That is what physics is like: to know what it is to do physics, you have to do experiments. Nor is physics 'really' its theories and ideas: it is just as 'really' its methods, apparatus, and data. Indeed, many people find it impossible to grasp what a physical idea is about until they

have used it to make sense of reality, which is what it is for in the first place."[84]

Few voices have been raised in questioning the extensive and expensive use of apparatus in school physics. Nevertheless, Thompson did arrive at a tentative conclusion: "This emphasis on practical work is in marked contrast to most European countries and it seems reasonable to ask whether this investment in time and resources is justified."[85] At the time that NAP was being published Halls found evidence that other European countries laid greater emphasis on class demonstrations than on experiments done by the pupils themselves. For example, West Germany allowed only 5% of physics teaching time for practical work, whilst the UK spent up to 50% of the time on experiments at the equivalent A-level stage.[86] More recently, further question marks have emerged, based on the students' views. A study by Denny and Chennell found that pupils associate NFSTP style practical work with:

- relieving boredom and generating interest;
- developing manipulative skills;
- discovering new things and testing ideas.

Their conclusions highlight a conflict between the pupils' views and statements made by the curriculum developers - the pupils are more influenced by the consideration of 'the pupil as a pupil' rather than the 'pupil as a physicist'.[87]

Overall, the preparation of the NFSTP materials involved the expenditure of many millions of pounds. Tawney estimated the cost to the Nuffield Foundation as £5m, a figure which must have included the £1.3m for the O-level science projects and the £0.4m for the A-level projects. John Maddox, then the NFSTP Co-ordinator, expressed the view "....that for every £ we [the NFSTP] have spent certainly local authorities have spent at least another £ and possibly as much as £5 or £10. So the actual amount of money that has gone into this work is quite considerable..."[88]

Although LEA finance, especially for apparatus, has influenced the capacity to promote or restrict the uptake of the Nuffield physics projects, finance for NAP apparatus is but one, albeit an important one, of a wide range of factors that influenced the diffusion of NAP. Clearly the introduction of NAP required a considerable commitment by teachers, both to implement the course and to maintain an involvement with the time-consuming interactive teaching style.[89] Furthermore, there is a lot of extra work caused by the varied examination profile, with its teacher-assessed

Individual Investigation and the setting up and running of the Practical Problems paper. Teachers and pupils might consider NAP interesting but they also find it hard work. NAP requires extensive laboratory space, lots of apparatus and storage space, and, critically, good technician support. A shortage of technician time would seriously jeopardize NAP.

Obviously not all teachers, schools and LEAs can accommodate the financial commitment, and feel happy with, the teaching style recommended by NAP. Monk has identified a particular problem for such physics teachers, where expensive pieces of apparatus remain on laboratory shelves unused or rarely used, despite extensive efforts to provide in-service training.[90] In other words, even if some of the apparatus is made available it will not necessarily be used, and perhaps cannot be used by the teachers involved. However, with the increased range of 'Nuffieldised' materials, text books, apparatus and examination syllabuses, the majority of physics teachers felt that it was unnecessary to 'go all the way', to use the distinctive NAP examination and encompass all the NAP innovations. But the very nature of the published NAP material, based as it is on the links and threads deliberately interwoven into the course, has meant that the NAP Units were not a marketable proposition to be sold separately. The one exception appears to be Unit 9 *Change and chance*, which has attracted a lot of international interest .

In addition, there has been a conflict of opinion over the reduced 'syllabus' content in NAP and the pressures this can generate in Higher Education institutions, as well as within the schools. Woolnough provides a good example in one of his school 'cameos': "The department had flirted with Nuffield A-level physics in the late 70s, and for three years had one set taking Nuffield as an alternative to the traditional 'A' level course. This was introduced, experimentally, in response to one feeder school who were doing Nuffield physics as 'O' level. But it did not prove popular with either the staff or the students, who would keep comparing their own progress with the apparently greater amount of physics being covered by their peers on the traditional course, and so after three years it was dropped. The natural enthusiasm of the department lay more with the structured content of formal physics and with electronics, than with what they perceived as the more tenuous outcomes of Nuffield. The thought of the problems inherent in having 120 students doing 120 different investigations in the limited laboratory space more used to handling practicals in pre-boxed form, also proved too traumatic to encourage a wholesale introduction of the Nuffield course."[91]

Finally, the NAP project was conceived in a period of great optimism and expansion. Nielson and Thomsen list some consequences:

> "The old, dull topics were ruled out, and the heart of physics admitted [into the schools' curriculum]. And as every physicist knows, this is interesting in itself! As a result of scientific thinking, tests were performed to measure the success of the new methods and research in physics education was institutionalized and spread rapidly in the western world."[92]

Diffusion research, for example, began to investigate the implementation of discussion-based, inquiry-orientated approaches to teaching, as advocated in NAP, and found that "....what had, at first, been described as 'resistance to change' was coming to be viewed instead, as the cumulative effect of 'barriers to change'."[93] For many varied and complex reasons, some of which can be found in what happened in NAP, a 'formidable gap' can develop between the intentions of central project teams and the implementation by teachers in schools.

The NAP project, like all the NFSTP developments, has been called a centre-periphery approach to curriculum renewal. Common features of this model are:

1. the curriculum materials, teaching methods and assessment are 'crucial for improved learning'; and
2. carefully chosen 'experts' will produce quality products for all school teachers.[94]

The origins of the centre-periphery model can be found in the 1950s curriculum projects in the USA.[95] However, sharp criticism of this model has been widely reported in the science education literature: the assimilation, development and dissemination of centrally produced materials was criticised for its apparent elitism, a lack of democratic influence, remoteness from teachers' needs and a reduction of teachers' professional status, to have all the thinking done for them by a central expert team. In reaction, this has led to wider dissemination in the practice of curriculum renewal, as witnessed by the move in the late 1970s and early 1980s towards local curriculum development[96] and then to hybrid projects, such as the Secondary Science Curriculum Review.[97] So that in 1984, Tony Becher, who helped initiate the centre-periphery model for the Nuffield Foundation, indicated "....that the kind of curriculum project model which had been used for the original Nuffield courses was now outdated and we [NCCT] should be looking for small scale lucrative projects which would produce quick returns."[98] The enormous financial commitment by the Nuffield Foundation could not be replicated in the new curriculum institutions.

Against this rejection, the late Lawrence Stenhouse reflected that the 'curriculum movement era', typified by the NFSTP, "....will look better in terms of profit and loss than will those of its expensive successor, accountability. It has stored a lot of capital which will be invested in in-service education in the next decade."[99] Keohane lists some of this 'capital':

-the co-operation and assistance of equipment manufacturers;
-the design and production of relatively low-cost apparatus;
-the publishers' investment in supplementary and complementary materials;
-the manufacture of films and film-loops;
-the development of examinations;
-the stimulus to create teachers' centres, the Schools Council (and the NCCT) to ensure continued curriculum discussion;
-the supportive programmes on radio and TV;
-the national recognition given to science teachers;
-the interest of the professional scientific institutes and their development of curriculum journals;
-the association of prestigious academics to bring scientists and teachers together;
-the financial investment by industry and the LEAs.[100]

Other changes have only become apparent after a substantial period of time, especially those related to teacher development and self-critical curriculum planning in schools. For example, the introduction in 1986 of the GCSE examination, a replacement for the GCE O-level and CSE examinations, provided verification of Stenhouse's prediction. Within the Nuffield-Chelsea Curriculum Trust (NCCT) the Nuffield O-level publisher, Longmans, reported an unexpected increase in sales: "We had expected this series [Revised Nuffield O-level] to decline significantly with the introduction of GCSE. In fact the decline from 1985 is very slight, and in the case of Physics, sales in 1986 are actually higher."[101] The quality and far-sightedness of the Nuffield physics materials had generated another resonance with teachers wishing to select constituent parts for teaching GCSE courses. As if to amplify the predicate, the 1988 Education Reform Act indicates that future curriculum reform will centre upon individual schools and even more teachers will need to turn for inspiration towards quality materials and ideas, some developed in the curriculum movement era.[102]

In summary, Nuffield A-level Physics has been successful in the sense that teachers are aware of the project and have been influenced by, and use, quality ideas, materials and apparatus specially developed for the scheme. NAP's distinctive examination is taken by about 20% of the total A-level Physics entry. Other A-level examination syllabuses were quick to incorporate the 'best' ideas from NAP. In particular, equipment and experiments designed for NAP have been integrated into other syllabuses to such an extent that equipment manufacturers no longer list NAP apparatus separately. The NAP Teachers' handbook recommends an upper limit of 16 pupils to an A-level physics class, and all equipment requirements are organized around this number. Perhaps this positive statement by the NAP Organizers has helped to set a reasonable limit in all A-level physics classes, provided, of course, there are enough A-level students opting to study Physics in the first place. NAP is now accepted in universities and in some cases NAP pupils, teachers and team members are integral parts of higher education institutions. The NAP examination provides a basis for teachers' professional development and the valuable examination meetings provide the opportunity for a democratic exchange of ideas between teachers, Examiners and team members.

The question of elitism remains open to further debate. NAP exists within whatever elitism is already built into the A-level structure. There is evidence that NAP may be best suited to above-average ability students. However, most of the schools using NAP, about 80%, are from the state sector of education, where many pupils have open access to their sixth forms, if not to NAP. It seems as though McCulloch's 'elitist vision' for NOP, is not as apparent in NAP. Also the course evolved, initially, from the desire to liberalize and broaden the A-level curriculum, and only later became a high quality physics course.

However, the NAP Organizers were able to learn from mistakes made in the O-level projects.[103] For example, NAP dissected the idea that there was one uniform experiment and developed a variety of experimental tasks throughout the course, and emphasised an open, interactive, approach towards teaching. The variety of tested teaching and learning techniques in NAP, plus the quality of the Nuffield physics project materials, resulted in rapid and extensive adoption by university departments of education for PGCE teacher training.[104] New physics entrants to the profession sometimes met only Nuffield ideas and apparatus: "In 1973, he [or she] would find a very structured and intensive course awaiting him. He would find a newly-built laboratory filled with gleaming new demonstration apparatus and sets of class apparatus developed for the Nuffield course and this lab would be the focus for him, and his group of twelve other physicists, for the year."[105] As in some schools, these university departments received a special grant for Nuffield apparatus.

On the very first occasion when David Malvern first met his PGCE Tutor, Philip Heafford, at Oxford University in 1968, he was presented with and asked to purchase a full set of NOP materials and throughout the year was trained to teach Nuffield physics. At this time, tutors tended to use a mixture of published and trials materials in their courses.[106] It was far from certain that new physics teachers would be involved in schools that had adopted NOP or NAP, however. On the whole, in the late 1960s and early 1970s, initial teacher training was fully committed to the Nuffield physics schemes and this may have influenced later decisions by some teachers to adopt or adapt NOP and NAP.

Research in science education expanded rapidly in the early 1970s, much of it stimulated by the NFSTP and Schools Council activities, and often based in university departments of education. In physics Nielsen and Thomsen identify three problem areas evolving from the research. The first is that the majority of students did not find physics interesting and so it seemed futile to concentrate on a subject-centred approach to curriculum renewal. Secondly, gender differences exist in physics, where girls' attitudes and achievements are, overall, worse than those of boys. And, thirdly, that physics is not readily understood by the majority of students.[107] Ogborn recalls that these issues had not yet emerged in sufficient detail to be fully incorporated into NAP, although a lot of effort was spent in trying to present the physics in an interesting and relevant way. Research by Pell has indicated that adoption of NAP might be a solution to generating student interest in physics.[108] The question of gender issues was not considered in detail, although NAP team members, particularly Bill Trotter, were concerned about the reactions of girls, and Ogborn was very conscious of this in writing the Students' books.[109] Meyer's study into reactions of pupils in the NOP trials had conclusively shown that this physics course had generated a marked improvement in the attitudes of girls.[110] Therefore, it is surprising that more effort was not made in getting girls' schools involved in the trials and in focussing more of the dissemination activity towards girls' schools. The NAP course raises social issues, particularly in Units 1 and 9 as well as in the Long Answer examination paper, which are known to be of particular interest to girls who study physics.

The NAP course was developed in a time of great uncertainty for the future of the A-level examinations and echoes of the debate are to be heard in the 'Higginson Report'[111] calling for leaner and tougher Alevels. NAP is lean and tough ! In any renewal of A-level syllabuses and processes, NAP can provide future curriculum projects with a successful, quality role model, with much built-in flexibility. But at the same time it is worth considering Archenhold's views:

> "I remember thinking at the time, and I don't think that 20 years has really made me change my view, that some of the ideas, particularly towards the end of the course, were somewhat sophisticated. These ideas were rather too ambitious given the fact that a larger proportion of 16 year olds were staying on in the sixth form at that time. If anything what was needed in the sixth form was a course which recognized their particular aspirations and abilities: a physics course which was in some way differentiated and extended the more able but, at the same time, allowed the less academically able to cope. I know that attempts were made in the NAP course to enable different groups to stop at different times, and I applaud that. In itself this was an innovation that was good at that time."[112]

What the take up by schools shows is that NAP as a whole was not just an innovation that was good at the time, but that it remained good over time. Its original version was in use from publication in 1972 to revision in 1984. In its revised form it continued with minor revisions to be examined until the end of the millennium, with its final examination in June 2001.

CHAPTER FIVE
Institutionalization and Revision - the emergence of the Nuffield-Chelsea Curriculum Trust

The growing ambition to place the NFSTP in an academic institution was eventually realised when the Trustees created a new curriculum renewal institution, called the Nuffield-Chelsea Curriculum Trust (NCCT), at Chelsea College. For some time before the first NFSTP publications appeared in the summer of 1966, the Foundation expressed the hope that "...the work which the Trustees initiated in the field of science teaching would encourage universities and other institutions to make a direct and continuing interest in this activity...Many aspects not so far covered by the work of the Nuffield Project will be given attention during the next few years; and there seems every promise that, when the Project itself comes to an end, its work will be subject to continuing re-appraisal and re-development, so that the teaching of science in schools need no longer be in serious danger of becoming obsolete and ossified."[1]

The appointment of Professor Keohane, Professor of Physics at Chelsea College, on a 50 per cent secondment arrangement, indicated the Trustees' wish eventually to involve this institution in their planned continuation because "....there is now likely to be at least one major university-based organisation concerned with the general problems of science education."[2] Furthermore, the Trustees were aware that the University Grants Committee (UGC) had established an Academic Advisory Committee to guide the development of the College and among its approved policies was the intention to establish a centre for studies in science education, firmly based in academic research and closely linked to the existing faculty in pure and applied science: "The main need is for the establishment of an environment where long-term revision, continuation and extension of these and other projects might be integrated with the many other research activities which have a special and particular interest to the science educationalist. The effort could well be unique in science and will not only extend the work in curriculum development to evaluation and examination studies but also to such fundamental problems as those associated with learning mechanisms in science."[3]

Preliminary discussion between Dr.Malcolm Gavin, Principal of Chelsea College, Professor Keohane and officers of the Nuffield Foundation, held during the Autumn of 1966, proposed that the Centre would initially concentrate on the Physical Sciences. It was hoped that Mathematics and the Biological Sciences would be included at a later stage. However, there were members of the NAB Consultative Committee who felt that Biology might prosper in a continuing development centre of its own. In any case, both the Nuffield Biology projects would transfer to Chelsea with the rest of the NFSTP, so no immediate decision was needed.[4] Chelsea College had found a suitable site at Parsons Green, Chelsea, and requested a grant of £135,000 from the UGC towards the purchase of the building. Initially, the Centre was housed at a Chelsea College annexe in Pulton Place and at the end of 1968 moved to an adapted factory building at Bridges Place, Chelsea.

Gavin solicited the help of Sir Nevill Mott: "The U.G.C. Sub-committee on Education of which Ashby [5] is Chairman is reviewing all new university education proposals during the next few weeks [April 1967]. Since we first announced our plans for Chelsea several other establishments have come forward with very similar proposals for Science Education....Apart from Keohane and our existing involvement with Nuffield, we already have on our staff, both in the Centre and in the Science Departments, a number of dedicated enthusiasts. No doubt I am biased on this issue but if you agree that there are merits in Chelsea for Science Teaching it would help our cause if you [Mott] would have a word with Ashby."[6] On 1 August 1967 the Nuffield Foundation transferred administrative responsibility for the NFSTP to the Bursar's Department at Chelsea College. The Trustees delayed any detailed decisions about the transfer of surplus funds accruing from the sales of published NFSTP materials but expressed an intention to help Chelsea College.[7]

In an unexpectedly short period of time the Centre for Science Education was formally established at Chelsea College, University of London, early in 1968. Professor Keohane was appointed as Director and established the first Chair in Science Education in Britain. A generous gift by the Shell International Company enabled the Centre to extend its programme to include Mathematics and Dr.Geoffrey Mathews transferred from the Nuffield Foundation to become Professor of Mathematics Education.[8]

As income from sales of the NFSTP O-level publications rapidly accelerated during 1967 and 1968, the independent charitable status of the

Nuffield Foundation became more problematic. So in December 1968 the "....Trustees had a full discussion about the Foundation's policy with regard to the income derived from the curriculum programmes (in particular, the first three of these - Science, Maths and Modern Languages) and about the ways in which various future obligations arising out of these programmes could be met."[9]

Their first obligation was to meet the publishing costs. Thereafter they itemised the following provision:

1. maintaining the team which handles the Foundation's side of the publishing programme;
2. arranging for minor revisions of the courses;
3. making *ex gratia* payments to the original authors;
4. giving 'after-care' to the projects that could not be provided by the Schools Council and the general education system;
5. preparing entirely new editions as the original materials become out-of-date, to ensure that the revised Nuffield courses continue to meet educational needs.

It follows, then, that the Trustees decided to ask the university institutions in which the projects had been placed to accept responsibility for this supervisory role. During the next seven years, 1968 to 1975, two-thirds of the publication income would be available to Chelsea College, for science and mathematics, and the University of York, for language, to meet the needs listed above. The Trustees demanded a yearly report and requested that a Nuffield Continuation Fund Committee be established between Chelsea College and the Nuffield Foundation with Dr.Malcolm Gavin acting as the Chairman.[10] The Nuffield Foundation was clearly expressing its wish to disencumber itself from a continuing long-term responsibility in the field of curriculum renewal.

The Director of the Nuffield Foundation, Brian Young, liaised with Gavin to set up a core Nuffield-Chelsea committee, consisting of Professors Mott, Burnett and Nyholm from the NFSTP Consultative Committees as well as Keohane, Becher and Young from the Nuffield Foundation.[11] Quite soon after this Brian Young indicated his intention to step down as Director and become Director General of the Independent Television Authority. He was succeeded by Professor C.C.Butler, FRS. Clifford Butler [12] had already helped precipitate the formation of the NFSTP and had been an active member of both the NOP Consultative Committee and the Nuffield A-level Joint Physical Sciences Committee. Furthermore, his involvement in the Butler-Briault N and F proposals for the sixth form made him a valuable addition to the Continuation Committee as well as to the Foundation in general.

The Continuation Committee met at least once a year during the interim period up to 1975 and had typical working budgets of £42,200 in 1971 and £67,841 in 1972. The sensible publishing arrangements, made originally by the Trustees in 1965, ensured that the programmes initiated by the Continuation Committee were self-generating. For example, in 1972-73 the following schemes were being financed and planned:

1. revision of the Nuffield O-level science projects under the guidance of Grace Monger, Biology, Dr.Richard Ingle, Chemistry, and Professor Eric Rogers and Ted Wenham, Physics; initial funding: NOB £6,000, NOC £8,500, NOP £7,000, with a further £10,000 available for 1973-74;
2. advanced Sciences team members continuation work to oversee manuscripts through to publication and to deal with day-to-day correspondence: no costing submitted;
3. *ex-gratia* payments to original O-level Science authors and Junior Science authors: £4,325;
4. Junior Science revision and support to re-establish the project in the light of current in-service teacher training programmes: £3,000 plus a guarantee of £3,000 in 1973-74;
5. Combined Science expansion into the 9-11 age range to accommodate the growth in Middle School education: £10,000;
6. Secondary Science extension into the first year of open access sixth forms: £7,000;
7. Primary Science in-service materials: £1,000;
8. education uses of living organisms: Schools Council grant of £25,000, supplemented by a Nuffield grant of £2,000;
9. Jon Ogborn's thermodynamics study: £2,000;
10. Mathematics for Science Modules: £6,000 and £6,000 for 1973-74;
11. common 16+ examination studies: £5,000 and £10,000 for 1973-74;
12. small grants and overhead costs: £5,750. [13]

The Nuffield Continuation Committee maintained this overall style of investment until 1975, when the Trustees indicated their intent, after the seven year interim period, to divest themselves of the capital assets from the NFSTP and end their direct association with the continuation work. By this time, Lord Todd, who was very knowledgeable about the NFSTP, had become Chairman of the Managing Trustees at the Nuffield Foundation. In addition, the Trustees requested that "....with the hand-over of these assets, the title of 'Nuffield' should gradually be withdrawn."[14] From an early stage in the evolution of the NFSTP the Trustees had realized that each constituent project should not be a 'once for all' exercise and that there was an obligation to ensure that the materials and ideas were constantly being reviewed and up-dated. They hoped that suitable university bases could be established "....in the hope and expectation that, after the conclusion of the development phase itself, the universities concerned might be encouraged to take project team members on to their permanent staff."[15]

The apparent success of the Chelsea Centre, and its Nuffield-Chelsea continuation connection seemed to vindicate this policy: "The Trustees' earlier concern to institutionalize its major curriculum programmes, and to initiate new ones where possible in an institutional setting (e.g. the Project in Linguistics and English Teaching at University College, London, and the Classics Project at Cambridge) can now be seen to have been fully justified....The existence of the Chelsea Centre ameliorated many of the difficulties [in adopting the new curriculum], largely because of the willingness of the staff (who were properly engaged on other activities) to give up their own time in helping to cope with the large volume of calls for assistance."[16] The Trustees called for detailed discussions and negotiations with Chelsea College to involve:

1. the transfer of the entire copyrights and obligations for the NFSTP;
2. the return to the Nuffield Foundation of one-third of the proceeds from the sales in each calender year for its own general purposes;
3. responsibility for the Nuffield publications management under the editorial guidance of William Anderson;
4. guarantees that income from sales would be devoted exclusively to the promotion of future curriculum development in school science and the training of science teachers for schools;

5. the combination of Science and Mathematics continuation work.[17]

Unexpectedly, a hiatus developed in the negotiations. A number of unforeseen problems emerged, some of them resulting from Chelsea College's draft memorandum to form a charitable trust incorporating the work of the NFSTP. In order to facilitate the proposed transfer, detailed financial estimates were prepared and it soon became apparent that no significant surplus would be generated in 1975-76: "First, the Project [NFSTP] has had to recognise that there is unlikely to be any substantial sum of money available for further curriculum developments for two or possibly three years."[18]

The cost of the publications unit, estimated at £40,000 in 1976, was traditionally the first deduction from revenue but there was a fear that income would not maintain the unit. Inevitable and annoying delays in publishing the revised O-level science materials, particularly NOP, helped exacerbate the situation.[19] In addition, it was noted that the management of the dimidiate enterprise was "....not sufficiently unambiguous to ensure that accurate commercial decisions are being made."[20] Finally, Chelsea College felt that the use of the name *Nuffield* was invaluable: "We think the retention of the word *Nuffield* is undeniably important and we hope the Foundation will agree to its continued use in some form, at least for a period of time."[21] In time, the association with Nuffield would prove to be a vital factor in defining the role of the NCCT and in maintaining its image and reputation in the field of curriculum renewal for a national market.

A full and frank exchange of views between the Nuffield Foundation and Chelsea College occurred on 5 October 1976. Both sets of representatives agreed that a suitable basis for the constitution of the new charitable organization would be a company limited by guarantee, with Chelsea College and the Nuffield Foundation as two equally interested members. The charity would be independent of each participating institution. Next, they recommended that the new Trust be called the *Nuffield-Chelsea Curriculum Trust* with a two-tier management system: a Board of Governors with three members appointed by the Trustees of the Nuffield Foundation and three by the Council of Chelsea College, together with a mutually agreed independent Chairman, and an Advisory Committee chaired by an educational consultant. They would be supported by a General Manager and a Chief Editor.[22]

Aside from the legal and administrative hurdles the Nuffield Trustees had to be reasonably sure that the Trust could be financially viable. They commissioned a report from Philip Sturrock, Managing Director of International Book Information Services Ltd.. He concluded: "There seems no inherent reason why this project [the Nuffield-Chelsea Curriculum Trust] should not be capable of financial viability and of generating sufficient income to support central staff and continuing authorship investment, given good management."[23] Tight managerial control is particularly important as one edition is gradually replaced by revised materials, to ensure that the new editions are published according to timetables. The report precipitated detailed discussions with William Anderson, who had been employed at the Nuffield Foundation's publications unit since 1961, and a series of monthly planning meetings were agreed. By the end of 1978 the Trustees were in receipt of legal papers prepared with the assistance of the Charity Commissioners. The Nuffield-Chelsea Curriculum Trust (NCCT) was finally incorporated on 5 September 1979, with Professor Kevin Keohane, then Rector of the Roehampton Institute of Higher Education, as its Chairman. The Trustees appointed John Maddox, at this time the Director of the Nuffield Foundation, Douglas Scott and Professor Tony Becher as their three nominees on the Governing Body of the NCCT.[24] The Trustees generously allowed their Accountant, Richard Marshall, to be seconded to the NCCT for at least a year, to ensure continuing finance and to act as a general manager. As a final gesture the Trustees approved the transfer of £173,509 to the NCCT and accepted Maddox's proposal that the Nuffield Foundation would not look for any monetary return from the sales of Nuffield labelled publications.[25]

As often happens in developments of this kind personnel changes create interesting alternatives. In 1976, Kevin Keohane decided to leave Chelsea College to become Rector of the Roehampton Institute. Clearly he could now assume the independent chairmanship of the Nuffield-Chelsea Curriculum Trust. On the other hand, Keohane's resignation posed questions for Dr.David Ingram, the new Principal of Chelsea College. In correspondence with John Maddox at the Nuffield Foundation, Ingram expresses his concern: "We too have started to consider how his [Keohane's] departure will affect such things as the Nuffield scheme and I know our staff at the Centre for Science Education are most anxious that its main features should continue in Chelsea unchanged."[26] Fortunately for all concerned Professor Paul Black accepted the offer to move to London as Head of the Centre for Science Education, Bridges Place. Before his transfer to Chelsea, Black discussed the full implications of the NCCT negotiations with Maddox.[27]

During the difficult and protracted negotiations to form the NCCT an attributive Board of Governors, chaired initially by Malcolm Gavin, dealt with the day-to-day continuation work of the Nuffield-Chelsea connection. Of particular interest to this study is the explication of the revision of the A-level science courses. At the low point in financial revenue, 1976, the continuation Board decided that the Nuffield A-level projects were now sufficiently established to consider the next phase in their development. Professor Keohane's close links with the Schools Council allowed him to report that the sixth form curriculum was likely to remain unchanged for 'at least eight years'.[28] If a major A-level revision programme was to be launched it would take up a considerable part of the Nuffield-Chelsea revenue. The urgency of this consideration resulted in the release of £75,000 from the Nuffield Trustees' publication reserve.[29]

In accord with this sentiment, Keohane instigated, in 1977, a number of preliminary Nuffield A-level surveys. The views of the publisher, Longman Group Limited, were presented by Michael Spincer: "If an educational publisher is to make a profit, and many do, he must be sensitive to educational needs and meet these in a responsible and realistic way."[30] He argued that the Nuffield A-level projects, consisting of 110 titles, were essentially published for the British market, which, at the time, was short of funds and expected to decrease in size during the next five years. So the question of cost would be one of the most important factors in determining the nature of the revision and the number of new publications. Therefore, it would be unwise for revision teams to consider any more major innovations; instead, they should build on Nuffield's reputation for quality:

> "My general feeling from discussions with teachers is that there is little wrong with physics and chemistry although views are rather more mixed about the chemistry special studies. Biological science seems to be of quite a different calibre and does not command the respect of the other two. Perhaps, in attempting to produce a balanced view of the subject, the biologists have lost that individual and slightly arrogant spark that even an organised project needs."[31]

Spincer had based his report, in part, on a series of four meetings, one for each A-level project, attended by school and university teachers interested in the projects, together with Maddox, Anderson and Keohane from the Nuffield Foundation.[32]

In what was to prove an important constraint on the revision of NAP, Spincer indicated the combined need for pupils' books to be "....rather closer to textbooks than those which exist at the moment....It cannot be entirely coincidence that the two projects which come closest to providing this type of book, O-level biology and A-level chemistry, are also the best sellers."[33] He recommended two, or three, pupils' books for NAC and NAP and a similar pattern for NAB, even though it needed a 'pretty radical re-think'. Finally, he wished to terminate NAPS, where large stocks of books remained unsold: "I do, however, firmly believe that it is very much in the Foundation's interest to reach a decision about the date by which this project [NAPS] will cease to be examined. This is surely better than letting it slip untidily into oblivion."[34] In the end NAPS hung on for a further 'untidy' ten years.

One of Paul Black's first jobs on his arrival at Chelsea was to edit a report on the likely effects of the Schools Council N and F concept on the NFSTP curricular approaches.[35] The study involved thirty-four teachers from both school and university and many were later recruited to assist in the A-level revisions. Inevitably, some of the work carried out for this N and F analysis would also provide evidence that an A-level revision was necessary anyway. The Government's decision in 1979 to reject, outright, the N and F concept finally paved the way for the NCCT to begin detailed planning for the A-level revisions.

The Nuffield Foundation's experiment to develop a Physical Science course and, hopefully, to help break down the arts-science dichotomy in the sixth form curriculum provides a concrete example of the difficulties experienced in trying to change the mould of post-16 education. By April 1979, the situation for NAPS had also reached a critical point, with few centres offering the subject and a continuing poor level of sales. Paul Black remembers that the decision not to revise and re-publish NAPS was reached rapidly but with regret - there were a number of people within the NCCT who had high hopes that the project would succeed. Leaving aside the educational merit of a combined physical science course, the NCCT could not expect anyone to be interested in publishing a new initiative and there was not enough money available for the NCCT, themselves, to publish a revised version:

"We could not escape from the agony that as long as single subject A-levels were there, and that Nuffield A-level Physical Science was in the market competing with them, then we had to satisfy too many conflicting constraints."[36]

Nuffield A-level Physical Science was examined for the last time in June 1988, with only 41 candidates from 5 centres.

The mandate to proceed with the revision of the other A-level projects was reached in the summer of 1979, allowing the publishers sufficient time to plan the volume and timing of their reprints of the original course, needed to fill gaps in their stock levels, before the new materials were scheduled to appear in 1983-84. At the time the NCCT Board estimated that £100,000 would be needed to revise NAC, NAP and NAB during the planning and development period 1980 to 1983.[37]

In organizing preliminary planning, Paul Black commissioned a number of surveys in physics and chemistry and arranged for small advisory groups to meet throughout 1980 to indicate the form that the revisions should take. True to form, the Chemists were the first group to organize a small Advisory Committee, chaired by Professor Malcolm Frazer, Professor of Chemical Education at the University of East Anglia: "The first action of the advisory committee was to approve, once again, the appointment of Bryan Stokes, Kings College School, Wimbledon, as general editor. The second decision was to formulate an '80 per cent unchange' rule: "We did this because we felt that the original Nuffield course [NAC] had been a success and there was no point in change for change's sake."[38] In order to make such definite proposals, at such an early stage, the advisory group had before them reports of consultations with schools, undertaken initially as part of the feasibility study for N and F, as well as views from departments of higher education.[39] Michael Vokins, a member of the original NAC team and a lecturer at the University of Bristol, prepared an evaluation of this work. The advisory group made a number of recommendations about general features in the revision:

- clearer specification of aims;
- more effective attention to applications by integrating work on them with the main course;
- attention to skills, especially comprehension and communication;
- more emphasis on calculations;
- more provision for revision tests;
- more emphasis on flexibility of sequence.

They also suggested that the content revision should be divided into four broad areas: physical chemistry and thermodynamics, organic chemistry, inorganic chemistry, and a fourth group dealing with the changes in sequence and the rest of the course work.[40]

The physical chemistry group was chaired by Professor Frazer and included both Paul Black and Jon Ogborn.[41] The chemists' intention was to introduce a treatment of thermodynamics and its applications from a completely new perspective, starting with the concept of entropy and using simple statistical ideas to count the number of ways of arranging particles. This approach had been successfully inculcated into NAP, Unit 9: *Change and chance*, which had received wide international acclaim as way of introducing the Second Law of Thermodynamics.[42] There is a view that the consideration of entropy and its statistical nature, "....together with other innovations which lean towards mathematics and physics, gives the impression that the new course is slanted towards the sixth former taking 'straight' mathematics, physics and chemistry A-levels, ignoring any trend towards more catholic subject combinations."[43] Vokins chaired the organic chemistry group. In the original NAC course organic chemistry had received a fair amount of criticism due to its lack of depth and preparative skiIls.[44] Extensive changes went some way towards mollify the critics.[45]

The final working group was chaired by Alan Furse, Head of Science at Blundell's School, and their work mainly involved re-organising the inorganic chemistry topics and basing the subject even more firmly in the periodic table.[46] In 1977, Furse had been involved in Coulson's initiative to encourage flexible sequencing of the NAC courses.[47] The final structure of the Revised Nuffield A-level Chemistry (RNAC) course appeared to be more logical and coherent.[48] But, as in the case of NAP, considerable flexibility can be achieved by teachers even within a highly structured, carefully planned course. Finally, the RNAC course increased its emphasis on the role of chemistry in industry.[49]

In a planned A-level publishing sequence the RNAC course was launched at the ASE conference, early in 1984. Schools and FE Colleges began the new course in the following September, with a view to the first examination in June 1986. An unexpected oversight occurred in the liaison with the London Board, who were proposing that the new examination would not start until 1987. Owing to the administrative problems, the new syllabus that the NCCT were committed to give to the Boards with every new course, had been delayed in processing and had not been approved by the Secondary Examinations Council (SEC), nor by the subject committees of all the Boards: "It had now been agreed that in 1986 there would be either a single complete examination based on the new course or an alternative examination for schools which had used the new books."[50] This oversight prompted an undertaking by the NCCT Chairman, Kevin

Keohane, to write to the convenor of the Secretaries of all the GCE Boards to clarify the procedures of approving changes in the syllabus for inter-board examinations.

Quite soon after the formation of the NCCT, Paul Black had written to the Secretaries to commence dialogue on the new examinations and new courses. Moreover, in May 1983, Mr.H.F.King, Secretary of the Oxford and Cambridge Schools Examination Board, was invited to attend NCCT meetings to represent the interests of the Examinations Boards. Fortunately for the Revised Nuffield A-level Physics Project (RNAP) Paul Black's continuing association with the Oxford and Cambridge Board, and the NAP examination, had quickly resolved similar issues: "We do not think it practicable either to run old and new course examinations in parallel or to have choice within the examination so that it suits those who have studied either course."[51] In reply, Betty Fraser, Assistant Secretary to the Board, agreed with the principle of a clean break and offered to distribute a RNAP syllabus statement in the Board's normal posting to NAP schools.

Precursory NAP studies were initiated by Paul Black during 1979 and 1980 which provided much needed evaluation of the course. The first investigation was carried out by Bill Trotter, who arranged a series of informal meetings with 51 NAP teachers, both individually and in small groups of about ten. He also solicited written comments from 27 former NAP students who were currently at university and reading a variety of subjects, and visited a number of people concerned with apparatus developments. His 18-page report, with detailed Appendices, revealed that the NAP course was sufficiently flexible to suit individual school needs.[52] One outstanding problem, however, was pupils' insecurity: "The insecurity felt by students and presumably by their teachers, is undoubtedly the most serious criticism of the course, depending as it does on a number of factors."[53] Possible contributory factors were:

1. the teachers' guides were, in places, vague or tentative about what teachers were required to teach;
2. the experimental work was too often qualitative and lacking in precision, causing some pupils to become 'slapdash' in their attitude towards practical work and possibly physics;
3. the absence of a book, a Students' Guide, which was exciting and specified the course more clearly and directly to the students.

Teachers, of course, are heavily influenced by success in the A-level examination and in entrance to Higher Education. Trotter solicited a wide range of comments from the NAP course 'successes': "I was amazed to find that final year [university] students could remember so much about their A-level experience. This alone says a lot for the course !"[54] He detected a more favourable response from those students who opted to read physics at university. In a further set of analyses Trotter listed detailed criticisms and suggestions for each of the Units 1 to 10 and indicated a range of new apparatus which needed appraisal. It is unfortunate that Trotter's individual report was not published, owing, in part, to his untimely death in May 1981.

The second NAP study was conducted in 1979 by Maurice Tebbutt, a lecturer in physics education at the University of Birmingham, and, in time, an Assistant Editor to the RNAP course. Five years earlier, in 1974, Paul Black had supported Tebbutt's proposal to conduct a postal survey of 540 teachers (288 completed returns) who had attended in-service NAP courses. Tebbutt was interested in their views on these courses and about their degree of uptake of the NAP materials. In addition, both men felt that the work should be extended into informal but extensive case-studies of a few schools, since "....there has been hardly any evaluation of A-Level Physics [NAP] of this sort and this compounds the weakness of our in-course evaluation efforts."[55] The results of Tebbutt's interviews were not published but they did provide him with some useful insight into NAP in schools, which would benefit his extended interest in the project.

By 1979 Tebbutt was ready to dispatch a second survey by questionnaire to find out whether a revision of the whole or part of the NAP project was necessary, and to follow up his earlier research. There was some cooperation with Bill Trotter, who edited questions and included some of his own, and the overall results were made available to Paul Black. In June, Tebbutt's lengthy questionnaire was sent to a random selection of 200 schools, about half the schools entering candidates for the 1978 NAP examination, and he received 120 replies. The results were published in *Physics Education* and they represent an important piece of research related to NAP.[56] Once again there was an 'overriding impression' that NAP teachers were, on the whole, satisfied with the course. Most schools intended to continue with NAP. However, a revelation that was made in Tebbutt's preliminary report to the NCCT, which did not appear in the published version, indicates that those schools not continuing with NAP seemed to have been affected by some reports from former pupils and admission tutors that the project was not favourably regarded in university departments. Some establishments were even going to organize parallel NAP and traditional physics sets for this reason.[57]

Paul Black responded with the third NAP study, this time directed at all departments of Physics, Chemistry, Geology, Metallurgy and Engineering and to all Schools of Medicine in England and Wales. This enquiry consisted of a letter which explained the NCCT's plans to revise NAP, recorded that NAP attracted about 20% of the total physics examination entry, and posed six questions about Nuffield Physics and university entrance. The replies were summarized by Black in an unpublished report and showed that in fact all but 6 of the 181 departments that eventually replied to the questions said that they treated Nuffield applicants in the same way as other students. Black records some of the contrary replies:

> "One engineering department said that they would give slight preference to a traditional physics applicant if all other factors were equal. Two physics departments said that they checked mathematics more carefully for Nuffield applicants, one of these saying that for anyone with both Nuffield Physics and SMP Mathematics they would warn the applicant that he/she would have extra difficulties."[58]

Black's paper goes to some lengths to underline the few negative comments because of the 'light they might throw' on the detailed discussion for the NAP revision.

As a forum to debate the ideas generated in these NAP evaluation studies an Advisory Group, composed ot the original Joint Organizers, teachers and university physicists, was set up under the Chairmanship of Professor Ken Smith.[59] Black acted as convenor and arranged for the minutes of the meetings to be printed. It was on the basis of this group's final report that the NCCT decided on a full revision for NAP. Their first meeting was held on 28 April 1980 and Black explained that resources for the revision "....could not be on anything like the scale of the original project (15 man years), and that 1 to 2 man years would be a reasonable target - perhaps more if a strong positive case could be made."[60] There was a free exchange of ideas emanating from the evaluation studies and Chambers prompted a discussion that the use and manipulation of algebraic equations needed more stress: "It was felt that the course did help the physics ideas to be grasped better by those who were less mathematically fluent. Perhaps because of this, there was a temptation to avoid using the opportunities to press the development of numerical and algebraic skills."[61]

The Physics Advisory Group met several times during 1980 and had completed its work by October. A finaL version of its report[62] was presented to the Governors of the NCCT under the following headings:

1. **Publications.** The revised course should be published as two volumes of Teachers' Guide and two volumes of Students' Guide and a series of background booklets. This was a radical shift from the 23 original NAP publications (8 Students' Books, 8 Teachers' Guides, 2 combined Students' and Teachers' Guides, a Teachers' Handbook, a Supplementary Mathematics Guide, a Students' Laboratory Guide, an Apparatus Handbook and a background reader *Physics and the engineer).*

2. **Examinations.** The definition of a course by its printed books can create a too rigid situation. A procedure should be arranged to enable changes relevant to the examination and the syllabus to be published and distributed cheaply. Eventually a booklet *Examinations and Investigations* was published[63] and, at a later stage, the Nuffield Post-16 Physics Group was established to coordinate examination and syllabus changes.

3. **Overall Structure of the Course.** The NAP course was original and far seeing. In order to maintain this position a low level 'mend and infill' revision strategy was rejected. But at the same time the Advisory Group recommended that the overall shape of the course should be kept in mind and that flexibility should be enhanced by exploring a variety of sequences through new units.

4-7. **Detailed modifications to the course and proposals for new materials.** Some topics in the core A-level physics syllabus were not covered explicitly in NAP, namely statics, kinetic theory and thermal conduction, and they had to be written into the new Unit A: *Materials and mechanics* and new Unit G: *Energy sources*. More material was included on the nucleus and on energy supply and management.

The successful electronics materials were updated to Unit C: *Digital electronic systems* and further linear electronic circuits, built around operational amplifiers, were included as Unit I: *Linear electronics, feedback and control*. Further, a role in the course for microcomputers was formally incorporated into the revision plans.

Many of the NAP topics remained in the revision plans but in some cases the presentation was changed significantly as can be seen in Unit K: *Change and Chance*. John Harris' article *Revised Nuffield advanced physics* [64] discusses this aspect of the revision in careful detail.

8. **Scale and Organisation of the Revision.** The Advisory Group suggested that a number of experienced teachers should be located to generate the new material. The funding constraint discounted a full-time team of writers and this meant that the ‘teacher writing model' was inevitable. This had the disadvantage of more part-time writers but there was the added problem for the Organizer and General Editor, to edit all the writing styles.[65] The progress of the revision needed a consultative committee to help guide the work.

9. **Other Papers.** Members of the Advisory Group had produced detailed papers that needed close scrutiny by the eventual course Organizer.

The long awaited reports on a minimal core syllabus in A-level physics from both SCUE and the GCE Examinations Boards were published at this time.[66] Paul Black was a member of the SCUE Working Party, chaired by Professor Mott, and he was able to keep the NCCT revision groups fully informed: "I [Black] have had so many transactions with SCUE since becoming a member of the Working Party I don't know whether I am writing letters to myself or not."[67] Paul Black's humour, good will and hard work had set the scene for a successful NAP revision.

In the twelve months from autumn 1980 to 1981 the momentum had appeared to go out of the NAP revision. Time was needed to organise personnel and to create a planned phase difference between the publishing schedules of the Revised NAC and the Revised NAP materials. The NCCT would not want to tie up all its limited working capital in stocks of books. There was some activity, however. In January 1981 Black wrote to all teachers of the NAP course, informing them of the revision and inviting comments and contributions for the new Students' Guides. He had begun to cast the net to recruit teacher editors: “About a dozen [NAP teachers] responded, their responses varying from extensive pieces of writing through specific suggestions for the improvement of a particular part of the course to expressions of interest or promises to reply at length later ... Nevertheless there are some useful ideas, and a few teachers who would probably be capable of writing adequate material once the right model has been found."[68]

Acting on behalf of the NCCT, Black arranged for Dr.John Harris [69], a Lecturer at the Chelsea College Centre for Science and Mathematics Education, to become Organizer and General Editor for the Revised NAP project (RNAP). During the summer of 1981, John Harris was given temporary secondment to spend about 75 per cent of his time on the RNAP course and 25 per cent to work on computers in the curriculum. By June, the NCCT had agreed to John Harris' appointment and he and Black organized the composition of the Consultative Committee, once again chaired by Professor Smith. Black and Ogborn had agreed earlier that they did not want to coordinate the revision themselves: "The main concern of Jon and I was that someone we had confidence in would do it [the NAP revision] and that we would leave him alone."[70] Black and Ogborn were active members of the physics consultative committee, however, with Ogborn writing a lot of new material and Black acting as a buffer with the NAP examining board.[71]

John Harris realised from a 'very early stage' that the imposed constraint of two Students' Guides was the key to the revision and that it was the most pressing job to establish an agreed printing model. Even before he officially began his work Harris experimented with different styles of presentation so that by the time that the Consultative Committee held its first meeting, in November 1981, he was able to suggest alternative models for the Guides.[72] The Consultative Committee quickly settled on the style of presentation for the Students' Guide and early in 1982 draft versions, using material rewritten from Unit 3: *Field and potential*, were trialled succesfully in about six schools. School teachers and university teachers were commissioned by Harris to revise sections of the existing course and propose new ideas. Some new topics would be included to cover the A-Level core syllabus. A list of the editors of each new unit and a very brief course outline are given below.

Revised Nuffield Advanced Physics

	Unit	*Suggested time(weeks)*	*Editor*
A	**Materials and mechanics**: As in Unit 1, but without	5	Roger Hackett, Christ's Hospital,

	Bragg diffraction. Including core syllabus statics; also momentum and kinetic theory of gases.		Horsham, West Sussex.
B	**Currents, circuits & charge**: Electricity and electrons. Much as original Unit 2. Kirchhoff's laws(core) made explicit. Without energy levels.	5	Nigel Wallis, Archbishop Holgate's School York and Mark Tweedle, The Grammar School, Batley
C	**Digital electronic systems**: Part of Unit 6: gates (NOR,NOT, AND, NAND.....); sequential logic; bistable, astable, memory, etc.. Uses and applications.	3	Mark Ellse Emanuel School, London, and David Grace, Eaglesfield School, London.
D	**Oscillations and waves**: Much as original Unit 4 without electromagnetic spectrum; a little more on resonance.	4	Charles Milward, Wellington College, Crowthorne, Berks., April Bueno de Mesquita, St.Paul's Girls' School. London, and Susan Ross, Godolphin & Latymer School,London.
E	**Field and potential**: Unit 3 without ionic crystal; with circular motion (core).	4	Trevor Sandford, Henbury School, Bristol.
F	**Radioactivity & the nuclear atom**: Unit 5 without photo-electric effect, with ionisation(from Unit 2) and a little more on the nucleus (binding energy,fission,fusion).	4	Paul Jordon and Peter Harvey, Highfields School, Wolverhampton.

G	**Energy sources**: Thermal conduction(core syllabus) treated via heat loss from buildings; sources and conversion of energy, including nuclear and 'renewable' sources.	3	Maurice Tebbutt, Faculty of Education, University of Birmingham.
H	**Magnetic fields and a.c.**: Pruned and streamlined Unit 7, including some a.c. from Unit 6.	5	David Chaundy, Malvern College, Worcester.
I	**Linear electronics, feedback and control**: Simple operational amplifier circuits; some general ideas about feedback & control in systems."Jobs to do" using both digital and linear electronics.	3	Wilf Mace, King Edward VII School, Sheffield.
J	**Electromagnetic waves**: Unit 8 without "physical optics" kit, and with less on propagation of e-m waves. With a little on Bragg diffraction(from Unit 1); e-m spectrum (from Unit 4) and Young's fringes.	4	Steven Borthwick and Peter Bullett, Rugby School, Rugby.
K	**Energy and entropy**: New treatment of some of Unit 9.	3	Jon Ogborn, Chelsea College, London.
L	**Waves, particles, and atoms**: Much as Unit 10, including the photoelectric effect and energy levels.	3	John Harris, Chelsea College, London.
	Total time for 12 Units	46	
	Investigation	2 x 2	
	Total course time	50 weeks	

Early in the editorial discussions it was pointed out that "....since many different authors are contributing it will be difficult to achieve a uniform style. But it is not intended that everything be rewritten by one individual in order to achieve uniformity. It must be hoped that by careful guidance and discussion an acceptable level can be reached."[73] Unfortunately, as the draft materials started to accumulate, concern began to mount about the quality of the writing, especially the Students' Guide chapter summaries: "It was felt that in some cases it might be better for these to be rewritten by somebody else rather than spending the time and effort necessary with the original author."[74] To sustain quality John Harris persuaded Ted Wenham to re-kindle his considerable editorial skills:

"The kind of job I am asking you to do includes:

Spotting any physics howlers.

Drawing attention to lack of clarity in presentation and other improvements that can be made.

Is the writing style of students' material appropriate?

Are there places where the same thing could be said more briefly? Is there repetition between Teachers' and Students' guides?". [75]

Wenham and Harris were in constant communication during 1983 and 1984, reading the various contributions carefully, looking for inconsistencies and rewriting some of the material. Wenham estimated that he read about five million words, probably read through the whole course about four times and worked through all the problems in the Students' Guides.[76] Harris, too, was acutely aware that he was the only person who had got any daylight hours to spend on this work and that for all the other editors it was a 'midnight oil and holiday job'.[77] Despite this, both Wenham and Harris agreed that there was some positive benefit from involving more people in the writing and that a change of pace and writing style enhanced the Students' Guides.

The first three Consultative Committee meetings, held between November 1981 and April 1982, devoted much time to discussing the content and overall plan of the new physics course. Even though John Harris was given considerable freedom to develop his own ideas he remembers a great deal of support from Black and Ogborn about the way to proceed: "Also in those early days Paul Black had the time to talk about physics."[78] Many hard decisions had to be made about removing topics and adding new ideas. Jon Ogborn, in particular, encouraged Harris to put new life into the course. He proposed a new Unit called "Systems, Control and Measurement", to act as an end-point, in contrast with the original one concerned with atoms as standing wave systems: "One deficiency of the present course is too little work on design of experiments: part of this is the failure of the 'Long Experiments'. The applied/engineering aspects could do with strengthening, especially near the end of the course. So part of the idea suggested here is to build in a little of engineering control and measurement as part of a solution."[79] After a lively debate Ogborn's radical intention was compromised. It was decided that some of these ideas would appear in the revised Unit I: *Linear Electronics, feedback and control.* Other innovatory ideas involved microcomputers and dynamics.[80] It was also agreed that the thermodynamics work in Unit 9 would be rewritten to conform to the approach being developed for RNAC. In all this, Jon Ogborn is seen once again as an innovative, creative physicist.

This time the A-level Physics project could not progress in isolation and Harris was given strong advice not to resist including topics from the national core syllabus [81] for A-level physics: "Amongst topics in the A-level syllabus not covered explicitly in the original Nuffield course are statics, kinetic theory and thermal conduction. Other important decisions were to include rather more on the nucleus and on energy supply and management (including nuclear power), and to revise the treatment of electronics."[82] A major constraint for Harris, then, was to accommodate these new topics and omit some 'less successful' work, without destroying the carefully designed structure that makes Nuffield A-level Physics unique.

By the middle of 1982 the overall plan for the course began to resemble closely the final published version of the RNAP . The number of Units had increased from ten to twelve. There were fears expressed by teachers that some units were becoming too long, for example the premier Unit A: *Materials and mechanics*. Moreover, the course itself, which now included traditional core items, was beginning to look bloated. It was evident that more material had been put in than had been removed, and the phrase *teaching for understanding takes time* was in frequent use once again. Originally, Black and Ogborn had constructed NAP to contain a smaller number of topics than the traditional A-level syllabuses. Confirmation was forthcoming in Crellin, Orton and Tawney's research: NAP covers 54 topics compared with other Examinations Boards' syllabuses in the range 61 to 77 topics.[83] The revising editors were, therefore, in a tempting position to add more to the course without removing tried and tested topics. In sympathy with the unease, John Harris conducted his own analysis of the NAP revised course, using the techniques developed by Crellin et al: "I find my fears confirmed rather than dispelled. We are likely to produce a course with as many topics to be treated as the average conventional syllabus."[84]

The physics Consultative Committee requested that Harris investigate the potential overloading further and present specific proposals for pieces of work that might be dropped. He identified parts of four subject areas for consideration:

- the detailed work on Bragg Diffraction;
- speed of mechanical and electromagnetic waves;
- parts of electric field and potential;
- parts of the wave nature of electrons and the standing wave model for electrons in atoms.[85]

At the penultimate Consultative Committee meeting held on 19 February 1983 there was "....little sympathy with the idea of completely cutting out any of the topics suggested in John Harris' paper."[86] However, suggestions were made as to how this material might be rewritten. The Governors of the NCCT were informed that a more radical and far-reaching approach to the revision had been adopted, and more money was allocated to the NAP revision budget.

Harris was confronted with a dilemma all too familiar to A-level syllabus designers in the Examining Boards. At times of major syllabus revision the inertia of the original course, plus the pressures to change and update, inevitably produce, at first, an overloaded syllabus. In Harris' case the 'old' NAP course, with its origins in radical renewal, were placed in juxtaposition with the need to accommodate a bloated A-level Physics subject core. Again, the inevitable result was an overloaded RNAP course, that was pruned twice within a few years of publication . It must also be noted that in the NAP developments Black and Ogborn were placed in the enviable position of being asked to 'start from scratch' and to be 'radically different' from traditional A-level syllabuses. They were even able to re-design their own A-level examination profile and procedures. Consequently, Black and Ogborn did not have to accommodate the full weight of tradition. But at the same time it is to their credit that they managed to produce such a 'lean and tough' A-level Physics course, perhaps even a 'model for all'.

It is interesting to note a small innovation, suggested at this time, that was easily absorbed into some of the units. An NAP teacher from the Blue School, Wells, M.R.Moore, mentioned to John Harris a series of novel

Home Experiments that could be included with some units. For example, Moore proposed experiments such as making a capacitor from household materials or observing the shear failure of jelly columns: "Dubbed (by the boys) 'Physics with your Phingers', the aim is to provide a firm cognitive base for many of the abstractions in physics through a number of practical tasks that may be pursued out of school hours."[87]

What distinguishes the evolution of the Nuffield A-level Science projects is the hard-won mutual consideration that exists between the NCCT, acting on behalf of the projects, and the GCE Examining Boards, that coordinate the special examinations. So throughout the revision period both the Boards and the Universities were kept fully informed of developments. In a judicious move the Consultative Committee invited Betty Fraser, Assistant Secretary to the Oxford and Cambridge Board, to attend its final meeting, held on 7 May 1983. She was able to hear for herself the concluding developments in the revision and discussed the procedures for the examination and the distribution of the NCCT's syllabus statement for physics.[88]

Earlier, in October 1982, Paul Black had been asked to convene a small group to review the current procedures in the NAP examination. Bob Fairbrother agreed to carry out this work. There was a general consensus that any reform in examination ritual should be implemented before the first RNAP examination in the Summer of1987. Small scale school trials were conducted, to test the group's recommendations to reconstitute the Long Answer and Comprehension Papers and to change the format of the Practical Problems Paper by introducing some longer problems. Teachers' views were actively sought at the November meetings for NAP teachers organised by the Oxford and Cambridge Board. The first recommendation received substantial majority support but the proposal to change the practical paper met with opposition: "At the Birmingham meeting there was a small but clear majority in favour of change; at the London meeting there was only a very slight majority in favour of the proposed changes with a large majority giving changes to this paper a low priority."[89] In December 1983 Paul Black wrote to all NAP teachers indicating that there would now be no change to the Practical Problems Paper, but the other changes would come into effect in Summer 1985.[90]

As an indication of the influential role that NAP teachers had made to the revision, and the importance attached to the NAP teachers' meetings held each November, the NCCT decided to launch the RNAP materials at a 'special meeting' held on Saturday 30 March 1985 at Chelsea College.

Advance copies of the first year materials were made available by the publishers and quickly sold out, and the surge of interest continued: "The Physics books, in particular, were published to instant acclaim and sold heavily in large numbers of schools in many authorities. The totals by the end of the year were well above expectation."[91] One book reviewer was reconciled in that the Teachers' Guides text was now in a continuous form, abandoning the original scheme of having right-hand pages devoted to the teaching sequence with detailed notes, not necessarily facing, on the left-hand page. The Students' Guides had done even better: "No more the weary groan as yet more little red books [NAP Students' books] are handed out!".[92] Another reviewer, not an NAP teacher, was so enthusiastic that he believed the RNAP course would create an increase in adoption:

> "The appearance of the revised course provides an opportunity for teachers who have not adopted Nuffield to reconsider their decision. They may have been put off like me [R.Chadwick] in 1970 by a course which looked like physics A-level for a physics degree at university or by the work necessary to introduce the original course in the sixth form. On both counts the new course is an improvement - more applications in the course (the word 'engineer' appears in most units and even in the index!) and more help for the student and teacher from the publisher's guide - and on better paper too."[93]

A less idealized opinion was expressed by Ted Wenham: "Some of the magic has gone."[94] But he still regarded RNAP as a 'very good course'.

In its earlier form, Nuffield A-level Physics was not well served by evaluation studies, neither during the developmental stages nor soon after publication. However, immediately after the first RNAP examination, in 1987, David Sela conducted an extensive evaluation exercise using interviews and questionnaires involving large numbers of teachers, and some pupils, participating in the new course.[95] After the 'newness' of the course had receded teachers were generally very enthusiastic about the revision, though there were specific aspects that caused concern. The restructured Students' Guides, which were at the heart of the revision, were well received by teachers but the following suggestions for improvement were made:

Content

- more detailed notes and summaries;
- more detailed practical instructions;
- more background reading;
- more basic questions and worked examples.

Structure

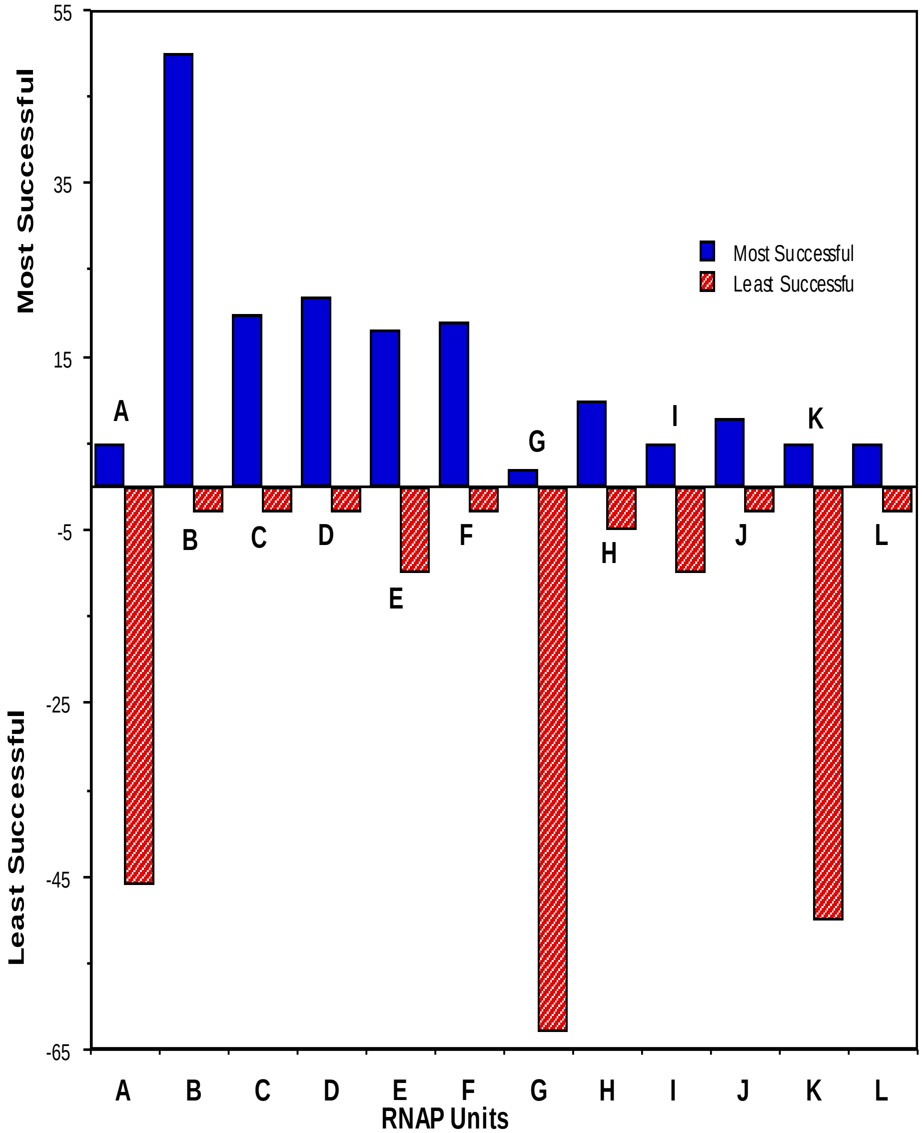
- divide into more volumes;
- integrate notes and experiments in the same section;
- introduce colour coding for sections (e.g.summaries, practicals, reading, questions).[96]

The students found the Guides heavy to carry and felt that the Unit summaries needed extending, and needed to include more applications.

Teachers used the course in a flexible way and most agreed with the specific changes made in RNAP when compared with NAP. Interestingly, 80% of the teachers used computer programmes, especially those specifically designed for RNAP. Many teachers noted that the length of the course and the nature of the examinations did not suit the less able candidates. Where a traditional A-level was running alongside RNAP, teachers advised the lower ability students to take the traditional course with its more clearly defined body of knowledge. This advice is a complete reversal of that given to students when NAP first appeared on the A-level scene ten years earlier.

It was clear, however, that most teachers agreed that some of the units were too long, vindicating John Harris' earlier fears. As it turned out the most recommended units to cut were also the least successful ones. The graph below indicates the most and least successful units in RNAP.[97]

Figure 5: Most and Least Successful Units in RNAP



(Adapted from Sela, 1988)

Clearly, the least successful units, according to teachers, were Units A,G and K, but for different reasons. Unit A was thought too long, diverse and not well focussed, while Unit G was largely done by students themselves and Unit K was difficult to follow. Nonetheless, Unit K is regarded by Jon Ogborn, the author, as a success, because it was a subject not taught well in many university courses, but which had been taught successfully to some A-level students.[98] A parallel students' questionnaire noted a high positive correlation between 'interesting-easy' (C,A) and the 'boring-difficult'(I,H) units. Students were less worried about Unit G, and a negative correlation between teachers and students was found in Unit A.

As a result of the concern about the overall length of the RNAP course, discussions were held in November and December 1987 involving many teachers as well as Awarders and revision Editors. After careful consideration a modest reduction was made, whilst retaining as far as possible the structure and style of the course.[99] Changes in the structure of pre-A-level physics teaching, involving GCSE examinations and the movement towards double-subject Science, however, forced the newly-formed Nuffield Post-16 Physics Group to recommend significant cuts in the RNAP course.[100] Using evidence from Sela's survey, and from consultations with teachers at the regular 'teachers' meetings', it was decided to make cuts in a number of units (especially Unit A). In a radical move, the two electronics units (Unit C: *Digital electronics systems* and Unit I: Linear electronics, feedback and control) and the thermodynamic unit, Unit K: *Energy and entropy*, became optional 'Units' and were subsequently examined in a similar way to the individual practical investigation, using teacher assessment and external moderation. The pupils carried out research and analysis on a topic of their own choosing from the content area of either 'Unit' and present a written report, hopefully dealing with a social, economic or technological aspect of physics.[101] Finally, in June 1990, SEAC approved the substantially reduced syllabus, which was examined for the first time in 1992.

This sequence of changes achieved a desirable reduction in syllabus content and a return to the level in the original NAP course. But the *ad hoc* way this was carried out introduced the problem of the course being seen by teachers as continually in need of change. The published materials and course structure had moved further apart, and both had moved further away from the original conception. Consequently, for some teachers at least the appeal of Nuffield A-level physics may have been reduced.

When compared to the commercial and academic success of both the A-level physical science revisions the results of the Revised Nuffield A-level Biology (RNAB) course appear modest.[102] Despite being radically different from the original course, sales levels were lower and there was a mixed reception in book reviews. Lock and Turvey, however, provided support in the form of letters indicating the advantages offered by RNAB as a course that could meet all the requirements for continuity from GCSE to A-level.[103]

The evolution over almost three decades of the Nuffield A-level Physics project is instructive as a process of long-term curriculum development and revision carried out within the framework of a carefully designed curriculum renewal institution - the NFSTP and then the NCCT. The need for such 'structural support' has been clearly identified by McKenney and Westbury in their historical case study of 'public' schools in Gary, Indiana. [104] Furthermore, Geddes took the idea one step further when she recorded DES arguments for an independent central institution, to replace the Schools Council, that could identify gaps in curriculum development work and, in addition, respond quickly in a self-critical manner.[105] As these criteria begin to multiply, it is necessary to consider in greater detail the notion of institutionalized curriculum renewal, set in the context of the Nuffield Foundation's initiatives, and involving the A-level Physics developments.

In exploring the notion of curriculum change and inertia, Waring has differentiated four institutional levels containing groups of people with an interest in the physics curriculum.[106] At the centre is the level of the individual classroom and teacher-pupil interaction. They operate within a second level, involving school and departmental factors: the attitude of the Head Teacher, the overall school ethos, the allocation of resources, science department politics, laboratory provision, timetabling, and so on.

Of interest here is Maden's view that the sixth form has almost become an institution in itself, with its own cultural and political life, founded as it is on the powerful influence of A-level examinations: "Based on grammar - and ultimately public - school values, it was very specifically conceived as a training ground for university. But it had a dual purpose. Following public school ideals of leadership and community within the secondary school, it was regarded that this separate unit within the school should not be cut off from the eleven-to-sixteen age group. The grounds for this were that the sixth form would provide leadership and set the moral, cultural, and intellectual tone for the whole institution."[107] The move towards specialist sixth-form colleges and the growth of A-level studies in Further Education institutions has, in some areas, created a more egalitarian ethos rather than the elite A-level community described above .

However, the intention of any curriculum development is for the ideas to become durably rooted in the school, and school practice permanently altered. The outcome, in its various forms, is referred to in the literature as *institutionalization*[108] (in schools) and must not be confused with the notion of *institutionalized curriculum renewal*, as carried out by the NCCT, for example.

Chapter 4 has noted the 'formidable gap' that can exist between the aspirations of the curriculum developers and the concrete achievements in the school. Reid refers to 'dominant institutional categories' which exert a powerful influence on what can or cannot be accomplished by curriculum planners.[109] The rapid growth in curriculum diffusion and evaluation research in the 1970s stemmed, in part, from the sense of failure felt by the planners and a desire to identify possible 'categories' maintaining the inertia against renewal. Other questions, at a school level, remained unanswered, however, and prompted research into the institutionalization of renewal in schools involving aspects such as cultural factors, or open, cross-curricular projects in classrooms.[110]

The size and importance of some projects, especially the NFSTP, meant that they acquire, in Jansen and van der Vegt's words, an 'institutional dimension' in their own right.[111] The schools' activities, therefore, will be exposed to influences from a third institutional level, involving, for example, the centralized, national curriculum projects sponsored by the NCCT. Some other influences at this level are from: the DES and HMI, the LEA, Science Advisers, BBC and ITV television, the Universities, Examining Boards, the professional institutions, the ASE, teaching unions, teacher education departments, publishers and local community institutions.

The fourth, umbrella-like institutional level involves wider political, economic and social factors controlled, in this instance, by Government institutions such as the NCC, SEAC and NCVQ, and perhaps, in the future, European Economic Community institutions.[112] It is clear, then, that as pupils move through the sixth form towards higher education they will be influenced by 'mediating institutions' at various levels.[113]

One such institution was the NCCT and one thing that emerges from this history of the Nuffield A-level Physics project is that the Nuffield Foundation's role in curriculum renewal was as much a model to institutionalize their initiative as it was to develop centrally-produced curriculum materials and methods. During the very early stages of the Nuffield projects Becher admits, however, that "... developments at Nuffield were incremental and step-by-step. We were into uncharted territory in setting up curriculum projects in the UK, so there was no real possibility of looking ahead and doing any systematic, long-term planning. One step just followed from another as the need arose."[114] But as a result of the rapid expansion in the NFSTP's programme and the Nuffield Foundation's aim to initiate other educational developments, the load on the Foundation's administrators, particularly on Becher, became excessive and a full-time NFSTP Co-ordinator was appointed in 1965. Also at this time the Trustees began informal discussions about their obligation to ensure that the projects were constantly kept up-to-date and about their ambition to find university bases for their projects, encouraging the universities to place the project team members in permanent appointments.[115]

The point being that the appointments have to be permament, so that in the course of time not only is the expertise preserved it can also be renewed. In the conclusion to one of his papers which began the NFSTP Farrer-Brown went as far as to state "... perhaps the main aim should be to improve (or where necessary initiate) the research activities of university departments of education" (see Appendix I), and saw a lively tradition of educational research in the universities as the solution to the scarcity of qualified research workers. By finding permament appointments for project staff, the NFSTP placed them in an institutional framework which kept their skills and experience available to curriculum development and permitted them to pass expertise on to others who in time could take their place. This far sighted policy was to do more than consolidate the hard won experience of one generation, it was to ensure it would be transmitted to the next.

By the time the Schools Council was fully operational, the proposals to establish the NCCT were formulated and the concept of this type of institutionalization for UK curriculum renewal had become a reality. Once again the Schools Council followed the Nuffield model. Geoffrey Caston, acting as the midwife for the birth of Lawrence Stenhouse's Humanities Curriculum Project,[116] wrote to Keohane on 18 August 1969, expressing his ambition to establish this project within a research centre at the University of East Anglia. He also requested 'briefing material' about the establishment, organisation and funding of the Chelsea College Centre for Science Education:

"I am personally convinced that one of the main strategic problems about curriculum development is how it can be institutionalized so that it is not entirely dependent upon short-term project funds. For this reason, the [Schools] Council has a strong interest in 'promoting' centres of this kind, and yours provides a most important model."[117]

The Nuffield Foundation's model to institutionalize its science curriculum renewals and revisions in the NCCT, formalized the need for a continuing concern about science education. The NCCT was formed around the kernel of the publishing unit set up by the Nuffield Trustees to oversee their own massive publishing exercise and was run for many years by William Anderson. His experience and continuity were invaluable to the physics projects:

"If there is one lesson to be learned from the experience of our twenty odd publishing projects, it is the value of appointing as a project organizer or general editor someone who has already had experience of editing and writing for publication."[118]

Within the NFSTP a high proportion of the O-level teams had considerable experience of writing for publication before they were recruited. In particular, Bunny Dowdeswell was such a brilliant editor that he was able to bring his less practised NOB team up to the same high standards.[119] The NFSTP and the NCCT realized the importance of continuity:

"It is significant that there has been continuity throughout the four stages of O-level and A-level projects in Biology and Chemistry and we are not pushed to identify new talent amongst the authors of the latest A-level revisions for future ventures in those two subjects... There is markedly less continuity in Physics - for reasons that are generally known." [120]

Even with their erratic developmental histories, the physics projects were still able to maintain some continuity involving the NAP project personnel based at Chelsea College. Such continuity tends to maintain ideas, writing styles and, importantly, a reputation for quality.

NCCT involvement in local curriculum developments centred in schools has uncovered quality control problems when trying to propagate the work into other areas. Paul Black has noted:

"On several occasions, several groups have completed [NCCT] work and produced their respective materials, but consideration of the completed collection has shown that the materials are unusable because of the diversity of form and level of presentation, and because a proportion of them are not of the same quality as the rest. The work of editing or re-writing such a curriculum then becomes substantial and the writers are in fact using the ideas of the local group as a resource rather than using their products."[121]

Evidence from the RNAP developments indicates that centrally administered, national projects also have difficulty producing writers with the necessary publication skills . Tall's essay review of an Australian Science Education Project(ASEP) historical case study suggests that this problem is universal.[122] In the case of the NCCT, it was its being associated with people who could produce good curriculum materials aimed at a national market which exerted a long-standing quality control mechanism.

The NCCT publishing office acted as a mediator between the wishes of the Trustees and the educational publishers. Therefore, the NCCT could approach a range of publishers in order to obtain the best support possible. On the other hand, educational publishers approached the NCCT with proposals, hoping to attach the name *Nuffield* to their projects. Decisions then needed to be made as to the appropriateness of any such projects. As one of the people involved with such decisions, Paul Black reasoned: "The NCCT has a reputation and simply producing publications for the sake of it is a way of losing that reputation and of wasting the resources. I take it that we are Trustees of a resource generated through schools which we ought to plough back."[123] In a sense, the work of the NCCT can be described as publication led curriculum development, where the publishers were rightly involved in the project and were represented on consultative committees.

It is not only the existence of an independent publishing unit that defined the institutional credentials of the NCCT. Other factors include:

- the continued use of the respected name *Nuffield* ;
- the reputations of the Trustees, Officers and General
- Editors, and a repository of tenured expertise at Chelsea College;
- a recognizable mode of working;
- a level of financial independence.

Historical details about the formation of the NCCT and its role in the revision of NAP demonstrate the importance of a permanent base in curriculum renewal and the benefits that accrue over many years. Its apparent stable structure and independence allowed for revisions, promotions and publicity as well as continuous interactions with other institutions such as the Examining Boards, HMI, SCUE, the Schools Council (later the NCC, SEAC and SCAA) and, of course, the Nuffield Foundation itself.

The Nuffield Foundation's three inceptive programmes, the NFSTP, Junior Mathematics and Modern Languages, began before the Schools Council existed and they were instrumental in publicizing the name *Nuffield* in the area of curriculum renewal. Some other projects, particularly in Classics and Humanities, began with, or later acquired, a budget shared with the Schools Council. Here Nuffield was not so indelibly associated with the projects, with responsibility for development, publishing and after-care resting with the Schools Council. Unfortunately, many of the Schools Council projects did not have the same hallmarks of quality and continuity so carefully collocated in the Nuffield Foundation's science enterprises. The termination of the Schools Council on 31 March 1984 hindered the process of revision for its projects and made access to the published materials difficult.

Within education some terms have, according to Reid, achieved a 'universal status'.[124] Certainly in science education the name *Nuffield* has been elevated to these heights and the NCCT helped to keep the word at the forefront of curriculum renewal. But within the schools, *Nuffield* is more closely associated with the particular course being used in the classroom. Here teachers and pupils are not so aware of the project's origins in the parent Nuffield Foundation, nor the NCCT, let alone what other curriculum work has been initiated by these institutions. At the same time, however, the NCCT perpetuated the involvement of NFSTP personnel along with their attitudes and methods of working. As such the NCCT could be regarded as having been a cosy enclosure providing 'jobs for the boys' in a wide range of curriculum research, mostly involving science, mathematics and technology. For instance, early negotiations between Mott, Gavin and Ashby about the linking of the NFSTP and science education to Chelsea College help to reinforce this impression.

There remained a close relationship with the Centre for Educational Studies, King's College, London (KQC), which, in 1985, incorporated the former Chelsea College Centre for Science and Mathematics Education and the King's College Faculty of Education. The NCCT at this time paid King's College for services and use of buildings, and acted as a focus for a two-way exchange of ideas for research and curriculum development. The NCCT did not specifically generate research income for King's College, but the NCCT was a curriculum renewal institution set within another institution interested in curriculum research. This situation helped bring the other side of the partnership to the fore, namely Chelsea (now King's). Within Chelsea there was a repository of tenured curriculum experts largely drawn from the NFSTP. Interchanges within the institutions meant that project developments were not solely dependent on NCCT funding. Harris, for example, was able to return to his tenured post when RNAP was completed. Perhaps lack of tenure for project Organizers could lead to tensions, especially when a project was drawing to an end.

Many of the people involved in the NFSTP, particularly in the A-level projects, became the educational establishment of the 1980s and 1990s. The Nuffield projects provided the opportunity for career development, particularly into university institutions, often set up or expanded to accommodate the curriculum explosion ignited by the Nuffield Foundation. Professor Paul Black, for example, was able to use his extensive knowledge of A-level examinations and teacher assessments, his experience of Examining Boards and his administration of the APU to advise the Government as Chairman of its Task Group on Assessment and Testing (TGAT).[125] More importantly, perhaps, was Paul Black's tenure from 1989-91 as Deputy Chairman of the National Curriculum Council, where he was able to use his experience of curriculum development to advise Government policy on the curriculum. The actions of some of the people able to wield power and influence within the NCCT have been closely scrutinised in this account. At the same time it has been possible to chart their career development from the NAP project. Their professionalism, honesty and integrity, so apparent throughout this history, seems to contradict such an obvious criticism as perpetuating self-interest.

At the early stages, however, jobs were found at Chelsea College for the A-level project Organizers, the notable exception being John Spice.[126] The Nuffield Foundation's wish to place some of its NFSTP personnel into permanent university posts had the desired effect in providing immediate after-care and, in some cases such as NAP, long-term revision strategies. Much of this Nuffield-related work was supplementary to the normal demands of the university appointment and it has been seen just how hard many people worked, not only in developing the projects but also in maintaining long-term stability. At the same time, these NFSTP personnel could use their experience, contacts and independent positions to motivate other curriculum changes.

An important example of this continuity and hard work over many years emerges from the evidence detailing the interaction between NAP and the Oxford and Cambridge Board. In consequence, Harris, and the NCCT, did not have to re-negotiate with the Examining Board. Instead, the links were enhanced by the NCCT inviting representatives from the Board to attend the various advisory committees. In contrast, a 'resurrected' Schools Council A-level project would require a completely new set of examining procedures coupled with protracted negotiations.

On the other hand, the Nuffield Foundation's policy associated the NFSTP and NCCT curriculum developments with the universities rather than the schools, although the example of RNAP provides evidence of close involvement by both 'institutions'. Nevertheless, the single subject Nuffield projects, both at O-level and A-level are seen in the literature as being aimed at the most able pupils and are closely linked to practitioner science; science regarded as the peak of intellectual attainment, with physics as the archetypical academic subject.[127] Moreover, the Oxford and Cambridge Schools Examination Board, which was responsible for the Nuffield physics examinations, was closely associated with independent schools and with a reputation for academic physics.[128] Although, it should be pointed out again that many more pupils from non-selective schools enter for the NAP examination than from the Independent and Grammar-type schools.[129]

Overall, these factors seem to support McCulloch's analysis that the NFSTP initiatives created an ethos of competitive individualism and the motif of excellence, while at the same time the NFSTP developments were closely related to an 'elitist vision' for science education.[130] This view, taken together with the formation of the NCCT so closely linked to a university institution, created the impression, at first, of the Nuffield Physics projects being locked away in *'Fortress Nuffield*'.

In particular, McCulloch readily supports his arguments by using statements by Eric Rogers. But it is apparent from this history that Rogers' vision was not held by all the people concerned with the NFSTP. Moreover, by the time that the second phase developments were being finalized many of Rogers' ideas were in decline, as McCulloch rightly acknowledges. The extended Nuffield A-level Physics, however, was based in a wide range of types of schools, it used democratic teachers' meetings to help its long-term revisions and was firmly rooted in the idea of partnership and cooperation. Perhaps this is one single subject NFSTP development that does not fit so easily into the elitist category.

The word elitism, so readily attributed to the NFSTP, can have many meanings. According to Professor Moravcsik something is elitist if:

1. it can be practised by only a small fraction of people;
2. its practitioners receive unwarranted rewards and prestige on account of their activities;
3. only a few people benefit from it;
4. its practice is restricted to a small group chosen by criteria which are irrelevant to the purpose at hand.[131]

It appears as though A-levels, in general, and Physics, as a subject, could be regarded as elitist. However, within these constraints, NAP provided a benefit for a large number of teachers and pupils, not only those who adopted the course. The Organizers and project team made a substantial effort to widen its appeal and successfully embed NAP in a wide range of types of schools.

Perhaps of greater importance to the large majority who will not study A-level, nor Physics, nor NAP, is the influence that NAP had on interactive teaching styles and practical investigations moderated in schools. Also, the lessons that can be gleaned from its mode of development may also have much to recommend in the problematic circumstances of curriculum renewal in general. The turbulent history of NAP is interesting in itself. But its difficulties with the universities forced the project to expound its ideas clearly, forcefully and widely. At the same time it was important to develop the notions of partnership and co-operation in curriculum renewal.

Amongst the various 'institutional levels', the universities represent one and only one of the demands being made on the schools' curriculum. In a way, Long was right in strongly supporting the schools' case in curriculum renewal and Black and Ogborn wise to establish, so successfully, a sense of partnership and cooperation. That partnership went a long way to protect NAP from being educationally elitist, despite its association with the NFSTP and the formation of the NCCT. Many of NAP's innovations transferred to other courses and levels and become available to a very wide range of pupils, so that even though there are now more, and more varied, institutional pressures, school curriculum renewal, in general, has learned and still can learn from the methods , successes and failures in NAP.

Finally, the key to the permanence of curriculum institutions like the NCCT lies in its financial autonomy. Even though its fiduciary resources were not extensive when compared to the Government and the other charitable foundations, the NCCT was able to finance revisions of its successful projects. Over time the NCCT established close working relationships with the educational publishers, who assisted in the revision process. Moreover, the profits from the sales of the quality materials were used to finance personal research and carefully considered new curriculum schemes. Comparable long-term success is also to be found in the School Mathematics Project (SMP), which was institutionalized at the University of Southampton.[132] The relative permanence and independence of the NCCT (and SMP) meant that it could respond quickly to changes in educational thinking, and so adapt and revise its quality materials for a national market.

Compared with the School Mathematics Project, the NCCT had a much wider field of curriculum responsibility, involving all three sciences as well as applications in technology. Unfortunately, limited resources only allowed the NCCT to fund one or two major projects at any one time. So, despite its flexibility and independence and potentially wide range of curriculum experiment, the NCCT was constrained in its response: "The Trust [NCCT] can continue in operation if the income from existing publications is used to generate new material which can regenerate the income in future. Not every enterprise needs to be profitable, but if too much income is expended on risk ventures which fail to attract support from schools, then its whole operation could fail."[133] At times of rapid and significant change the NCCT's muted response was a limiting factor.

Both the NFSTP and SMP realized at an early stage that their centre-periphery mode of renewal needed to be placed in a permanent institution. The 'centre' became the university base charged to keep abreast of changes as well as organizing renewal and revision. The 'periphery', the teachers in schools, are often limited by time and opportunity to respond to change in a meaningful way. In contrast, the finite span projects, characterized by the Schools Council, have come and gone, and in many cases, been forgotten. Howson noted the 'disastrously abject record' of such projects and was adamant that schools need the reassurance that people are at the 'centre' attending to emerging problems, answering questions and providing support, both in the subject area and in response to policy changes.[134]

Nevertheless, it could be argued that with the demise of the finite span project the curriculum field can open up again with new agendas and is able to draw upon the rich vein of material and ideas from the 'failed' projects. Furthermore, the PSSC project provided a 'single pulsed effort' and was never expected to make a permanent change when US Government funding ceased. What it did achieve, however, was a strong and lasting interaction between school and university physicists, plus a core of well-trained teachers able to exert their own influence at the school level, with its many and varied demands and constraints.[135]

But there was evidence of a re-awakening. In direct response to the 1988 Education Reform Act, the Nuffield Foundation once again became interested in the schools' curriculum, including A-level renewal. Among the reasons for the change of heart was that Government directives tend to be statements of intent rather than fully developed schemes of work. Very often no reference was made to the needs of innovation and change. As a result, the Nuffield Foundation decided to work independently in some areas (A-level mathematics) and, in others, with the full cooperation of the NCCT.[136] This change of emphasis was significant and from it grew the Nuffield Foundation’s Curriculum Projects Centre (NFCPC), which carried out work on economics and business as well as mathematics and sciences and funded others to develop primary history and data handling.

With respect to this atmosphere of ferment and change, we are reminded of some lines from T.S.Eliot's poem *Little Gidding*: [137]

> "What we call the beginning is often the end
> And to make an end is to make a beginning."

Further renewal continued in A-level sciences, with the revision of Nuffield Chemistry as an AS and A2 course and a completely new A-level physics project, Advancing Physics, developed by Jon Ogborn with the Institute of Physics. The latter inherited much from the original Nuffield design: radical; lean; tough; flexible; interactive; developing students’ skills in communication, numeracy, information technology, problem solving and so on.[138] An inheritance which illustrates the strength and endurance of the roots of NAP recorded in this curriculum history. For, as Eliot's verse continues:

> ".....A people without history
> Is not redeemed from time, for history is a pattern
> Of timeless moments...."

CHAPTER SIX
The Timeless Moments

This narrative is about the past: the origins of the Nuffield Foundation's experiment in A-level curriculum renewal and, then, the turbulent history of the Nuffield A-level Physics (NAP) project, which eventually settled into long-term stability and publications' revision, initially sustained by the Nuffield-Chelsea Curriculum Trust (NCCT). It is also about the people involved, their contributions, their interactions, the way they worked and their recollections.

The curriculum history that unfolds is interesting in its own right, as it sets down the detailed events and the actions of the people involved. But the history also serves a number of other functions. It puts on record for the first time what happened in the Nuffield A-level Physics project, which, as an act of scholarship, has intrinsic merit. But in this case it also serves to set the record straight. It reminds us that each of the Nuffield projects was developed in its own unique way and that it is too easy, as Black notes, for outside observers to erase the differences between each of the science projects.[1] Therefore this curriculum history complements the work of other researchers into the activities of the NFSTP.

For example, it has shown that when McCulloch makes too general statements about the NFSTP's 'elitist vision', frequently supported by Rogers' ideas, he fails to recognize the metamorphosis of the physics curriculum, especially the long-term, democratic role of the NAP. Moreover, the productive collaboration of Black and Ogborn in this process stems, in part, from the less successful start for NAP. In this way, the history of NAP contrasts with the other NFSTP developments.

Atkin's cogent analysis of the origins of the curriculum movement era reminds us that the first attempts to alter radically the physics curriculum in schools began in the USA with the Physical Science Study Committee. A classical centre-periphery project model was introduced using 'great minds' from the universities, lavishly funded by the US Government in order to prepare and trial high quality curriculum materials to be used by capable and experienced teachers in schools[2]. The ripples of this massive, single-pulsed effort were, of course, felt across the Atlantic, in Britain.

A general view persists in the literature that in Britain (more accurately, England, Wales and Northern Ireland) the initiative to renew the science curriculum was carried out 'by teachers, for teachers' and based, in part, on the SMA and AWST syllabuses. In reality only a small number of teachers were actually involved in the developmental stages of NOP and university physicists were closely active in the inception and the project details. In particular, the decision by physicists on the British National Committee for Physics to establish a specialist group to oversee school physics developments (the National Committee on Physics Education, chaired by Mott) provided the Nuffield Foundation with an academically respected source of ideas and information to assist with their own plans to finance US-style renewal.

Farrer-Brown's virtuosity and eloquence helped precipitate the Nuffield Foundation's first auspicious experiments in science education. In the early 1960s, Farrer-Brown, and the Foundation's Trustees, were anxious that Britain should 'catch up a bit', not only in science curriculum developments but also in university based educational research in general.[3] These twin ideas were raised independently at the Trustees' decisive 115th meeting on 8 December 1961. The gradual, and at times subconscious, step-by-step conjunction of the ideas eventually grew into an independent curriculum renewal institution, at first as the Nuffield-Chelsea Curriculum Trust and then as the Nuffield Curriculum Projects Centre.

In addition, Farrer-Brown also wanted to help the country catch up in a wider social and economic sense, hoping that creating more interest in O-level science would assist in breaking down the arts-science dichotomy (Snow's 'two cultures') in the schools, especially at A-level. He was emphatic that 16+ examinations (i.e. O-level) would be the place to begin, despite strong HMI and Ministry advice for the reforms to start at A-level. He argued that a 'majority' of students would benefit from the inceptive Nuffield projects. This raises the question as to whether or not Farrer-Brown realized that only a minority of the 11-16 age range, about 20%, could possibly be influenced directly by an O-level project.

Certainly, in Young's terms, Farrer-Brown's actions smacked of social control which would result in Britain having a majority illiterate in science.[4] In this light, there is some sympathy, too, for McCulloch's view that the origins of the NFSTP lay in an outdated view of education for leadership and an elitist vision for the O-level projects.[5] Here the leaders would emerge from what Farrer-Brown described as a 'majority', but which, in fact, was a minority.

However, it is interesting to note that from the outset Farrer-Brown suggested a *five-year* O-level programme for 11-16 year olds. He could have opted for a two-year examination course, which would have only been seen by those who elected to stay on to be examined after the school leaving age (at this time, 15) and, moreover, by only those who chose to do Physics.

Instead, Farrer-Brown interpreted an O-level course as something to be run over the whole of lower secondary schooling, thereby including the general education of the future arts and humanities specialists. This decision is completely at one with an attempt to break down the arts and science 'sides', at least amongst the able. For the time, Farrer-Brown was trying to do something that could be described as liberal for his 'majority', set within the limitations of the general education he was intending. So, in a sense, everyone's views about the origins of NOP are right, with the later analysis and its reference to ‘elitism’ by Young and McCulloch contextualized by the wider perspectives of comprehensive schooling. What they do not consider is that the possibility existed in NOP that these issues would have been addressed, at least to some extent, had McGill not died.

From the outset, then, the O-level Physics enterprise was different from all that had gone on before in Britain (excluding Scotland), including the SMA syllabuses. At a very early stage McGill was advised to adapt, not adopt, the SMA ideas. So McGill's course was based on concepts, introduced and re-introduced at various levels, and all reinforced by extensive pupils' exploratory experimental work and some teacher demonstrations. From the beginning the NOP course was not as linear as the other O-level projects, NOB and NOC.

The ideas for Year 5, the O-level examination year, began to overlap with possible A-level content, especially that involving concepts such as wave-particle duality. As a result, McGill was asked as early as January 1963, barely ten months into the project, to prepare his preliminary views on a likely A-level Physics course. But his tragic, unexpected death in March 1963 circumvented this action.

McGill's replacement, Rogers, a Physics Professor at Princeton University, imposed his eccentric will on the O-level project, producing brilliant ideas and expositions but awkward administration problems. It was the change in leadership that provided much of the ammunition for McCulloch's analysis and conclusions. It would be unfair to Rogers, however, not to reinforce the point that he was a brilliant physics teacher and that his drive and energy helped to create a high quality O-level course.[6] As it turned out, Rogers' persuasive influence and methods of working, plus the Foundation's 'secrecy rule', did impose themselves on Long, the first NAP Organizer. They led to a communications conflict, particularly with influential university physicists that created a major upheaval in the NAP project.

A number of authors have identified that the first NFSTP projects did enable the O-level physics curriculum to 'catch up'.[7] But it was the 'second wave' A-level projects that pushed the physics content, teaching methods, pupil involvement, equipment and assessment a long way ahead.

During Farrer-Brown's planning it became apparent that HMI and Ministry of Education officers were keen that the Nuffield Foundation got on with their reform at A-level. They felt that in the accelerating mood for comprehensive education it would not be possible, at that stage, to prepare science curricula for the real majority of 11-16 year olds. This advice was rejected by Farrer-Brown in his search for a way to help break down early specialization into the arts and science 'sides' in schools. Peterson has indicated that Mott was a leading figure among the critics of this traditional division, especially in the sixth form.[8] So, spurred on by discussions at the National Committee on Physics Education meetings, Mott was anxious that the Nuffield Foundation would soon initiate some liberal reform in the A-level arena.

About a year after the start of all three O-level projects, Mott, Nyholm and Swann petitioned the Nuffield Trustees to consider A-level renewal. By this time the Trustees were becoming aware of the high cost involved in such innovative renewal, especially in the NOP project. Radical departures in Physics teaching, including the cost of equipment development and its placement in schools, meant that the NOP project needed additional development funds.[9] Therefore, the Trustees were cautious about the added cost of A-level developments. The thought of expanding, long-term financial responsibility for the NFSTP schemes must have appeared daunting to the Trustees and set them thinking about strategies to relinquish direct responsibility, while at the same time providing a framework for further development work and revisions. It is here, too, that the origins of NCCT and NFCPC are to be found.

However, Becher's administrative dexterity contrived to establish a pilot-study phase for the A-level sciences during 1963-64. From the beginning it was the intention to develop two integrated Nuffield A-level courses in Biological Science and Physical Science with strong support, at this stage, from both Mott and Nyholm. A number of studies at this time attacked the subject specialization at A-level and its reinforcement of the 'two cultures' division. It was anticipated that by combining the science subjects in this way a broader balance of A-level subjects would be achieved. According to McCulloch, the social control was to maintain in public (independent) and grammar schools a unique blend of liberal traditions and scientific appreciation.[10]

Strong support for such reforms came from headmasters such as Lee, at Winchester, and Dancy, at Marlborough, both of whom backed Spice's proposals for a Physical Science (initially called Structure and Properties of Matter) A-level. In Lee's words:

> "I think this S.P.M. [Structure and Properties of Matter] might be an idea of first importance. I have backed John Spice all the way through over it, and would like to see him and us in on it for a further stage."[11]

Lee actively promoted this theme through the Schools Council's first proposals to improve the pattern of existing A-level courses during 1964-65. He argued for a two-level 'majors and minors' pattern: able sixth-formers would study two majors (each 8 periods per week for two years) and two minors (each 4 periods per week for two years) instead of three A-levels, whilst less academic pupils might consider more minor courses. All pupils would have to take non-assessed general studies.[12]

With this level of support, Mott's physics group met representatives of Nyholm's chemistry group, plus Rogers and Long, in July 1964, to establish a development plan for the integrated subject, Physical Science. At this crucial meeting conflicting impulses collided, with the irascible Rogers provoking considerable anger and frustration in Nyholm. Rogers' blatant provocation upset the equilibrium and cooperation so carefully established by Mott and Nyholm. Within nine months Nyholm completely reversed his thinking and suggested instead that a single A-level chemistry course (NAC) should replace the integrated approach. Detailed plans and financial arrangements had been prepared for the Trustees' approval in March 1965. Hurriedly, the plans and policy were changed, so that three equally weighted physical sciences projects were established: NAP, NAPS and NAC.

A major oversight occurred in all this activity. The three projects shared the same developmental capital set aside for the single Physical Science venture. Perhaps Maddox, the NFSTP Co-ordinator, did not want to approach the Trustees for more money in the light of the O-level increases. The resultant severe underfunding would initially put both the NAP and NAPS projects under pressure during 1965-66. Moreover, the very existence of the separate A-level projects, NAP and NAC, meant that they would be in direct competition, in the schools, with NAPS. In effect, this enlarged A-level programme helped to initiate the inevitable decline of NAPS, even before the project had begun.

Overall, the events support Hodson's view that "....the way that school science is perceived is not the end result of inevitable progress in the disinterested search for 'curriculum truth'. Rather, it is socially constructed, being the product of particular sets of choices made by particular groups of people, at particular times, in furtherance of their particular interests."[13]

The second wave A-level science projects were exposed to a wider range of 'particular' influences: the universities, changes in 11-16 schooling, debate about the nature of A-level, broader based sixth forms, parental and student expectations, and so on. In particular, for NAP, university pressure, combined with a late start, poor levels of funding, Long's isolation in York, a dispersed mostly part-time team, and a radical intention, all conspired to create an impossible situation for the NFSTP and activated Long's resignation as NAP Organizer.

There were two key issues in this conflict: one, the organizational methods employed by Long; two, the radical nature of the NAP course. Both were influenced, indirectly, by the NOP course. Long adopted the O-level secrecy rule and Rogers' autocratic style of leadership, probably further influenced by his role as a senior HMI for many years. His exposition of the NAP project was at fault, particularly to the SCUE sub-committee (the Liaison Committee). The poor presentation of his policy papers and first ideas were in marked contrast to the other A-level projects.[14] Furthermore, Long was not, in Young's words, a 'fighter' nor a 'thruster'.

But, on the other hand, Long was highly respected by his team as a physicist, as an advocate for the school teachers' role in A-level curriculum developments, and as a person. The early, chronic underfunding for NAP did not help; Long had difficulty in securing sufficient secretarial help and he reacted by employing mostly part-time, rather than full-time, physics team members.

Secondly, the NAP team's plans for a radically new course involving content and teaching methods in a coherent package, clashed with the universities' pre-conceived notions of a linear A-level course. Again, as in NOP, radical physics curriculum renewal is seen to be different, less linear, and certainly costing more money to develop, than the other science projects. Under these circumstances, the need for close partnership and cooperation between schools and universities, at least, is clearly illustrated in the events surrounding Long's resignation.

Obviously, the Nuffield Foundation wanted to play down the rift that had developed between school and university interests in the A-level physics curriculum. To some extent replacing Long by university-school Joint Organizers, Black and Ogborn, went some way to resolving the issue. But lessons had been learnt from the resignation, and from NOP, so the Joint Organizers were better prepared, but very short on time. Black and Ogborn were asked to start again with a clean slate and set themselves a 'fearful timetable'.

The notion of partnership was firmly established in the team and Black and Ogborn presented their first ideas in a clear and forceful way. Furthermore, Long had bequeathed many good ideas and papers, and the basis of an excellent project team. Ogborn was full of radical intent and was able to write these ideas quickly and clearly into curriculum materials for students and teachers. Black gave the universities confidence that their views would be heard, and his extensive experience in research and his attention to detail were invaluable, especially in the intricate arrangements for the novel testing procedures at A-level. Both men maintained close ties with the NAP project after publication, providing sensitive aftercare through their association with the NAP examination and the related teachers' meetings. Their concern was in marked contrast to many projects spawned in the curriculum movement era.

Evidence given in Chapters 3 and 4 indicates that the NAP project influenced the whole of the A-level physics curriculum on two levels. The first could be called the system level, in which the project focussed the attention of many teachers, particularly those in trials schools, on interactive teaching methods and novel content including many ideas not previously been considered part of A-level teaching: *viz*: wave-particle duality, statistical thermodynamics, elementary relativity, systems electronics, student led demonstrations, optional stopping points, multi-facet examination, teacher-assessed practical investigations.

Consequently, the experiences gained, plus the undoubted quality of the physics, quickened interest throughout the country.

A second level was the planned dissemination and subsequent diffusion of the NAP project ideas. It is beyond doubt that NAP has been successful in that it has greatly influenced A-level physics teaching, for although at best NAP examination entries reached about 20% of all A-level physics candidates, a number of studies suggest that NAP materials came to be used extensively in schools and many more teachers, in time, were influenced by the introduction of NAP ideas into other ‘traditional’ A-level physics syllabuses and text books.

It can even be argued that the 'lean and tough' nature of NAP, together with its abundance of 'core skills', has been more widely recognized and its processes have influenced post-16 curriculum development in general.[15] Even though all the Nuffield A-level Science projects were tied to the existing A-level structure and, in Fensham's words, ended up as "....an elegant and mentally stimulating pursuit of their science to complete the secondary education of an elite"[16], NAP did recognize the need to accommodate a more diverse sixth form, and over time many of the NAP's tried and tested strengths have become more generally applicable to the whole of post-16 education.

Moreover, many of the project's personnel, teachers and pupils went on to establish themselves in the universities. The story of Nuffield A-level Physics highlights the importance of school-university dialogue in A-level curriculum renewal. This exchange of views is often helped by intelligent action from the professional institutions, such as the Institute of Physics and the Royal Society. A notable feature of the Nuffield A-level projects was the active participation of university scientists, especially in important innovations like teacher-assessed practical work. The physics project's individual investigation had Awarders and Moderators drawn from university departments and the Bill Trotter prizes for the outstanding investigations were judged each year by an eminent university scientist. The way in which these 'limited remit' investigations, and their moderated assessment in large numbers, spread their influence into other A-level courses and into GCSE is an important conclusion from this work, and it supports statements made by Lock and by Woolnough.[17]

In contrast, however, Johnson's research carried out for the Oxford and Cambridge Board, entitled *Beloe to Baker: Thirty Years of Teacher Assessment and Moderation*, surprisingly does not register this influence from the Nuffield A-level projects.[18] In a similar way, Kingdon, at the

London Board, did not recognized the role that NAC had on A-level Chemistry syllabuses developed by the Board.[19] It seems as though more research is needed, in general, on the way that 'project examinations' have been perceived in Examining Board institutions, and their influence charted.

Individual schools are often reluctant to be involved in novel curriculum developments until suitable examination arrangements can be guaranteed. The experience of the Nuffield A-level Science projects suggests that "....examinations can be used to aid curriculum development and a teacher's diagnostic work without undermining their value as examinations per se. For this to occur, closer links between the examination system and teachers have to be established and teacher participation must play a large part."[20] Nuffield A-level Physics Awarders, for example, frequently used the close links and their annual examination meetings to discuss curriculum and examination changes with teachers and to encourage more people to become directly involved in the examining process. Teacher assessment of practical projects and investigations in these A-level courses influenced GCSE syllabuses and subsequently informed the National Curriculum. Moreover, the annual moderation of about 9,000 Nuffield A-level physics investigations provided an important model for practical assessment organization, especially for the large numbers involved in GCSE examinations and other A-level syllabuses such as JMB A-level Physics and the Oxford and Cambridge Board's own A-level Physics course.

A notable feature of Nuffield A-level Physics is the way it evolved over time, under the watchful eye of people in the NCCT and the Oxford and Cambridge Schools Examination Board. Gradual renewal came about as a result of examination feedback, course revision, changes in examination format, changes in investigation assessment and moderation procedures etc., many resulting from discussions at the annual meetings with teachers.

One picture that emerges here is that the initial high investment in money and intensive team effort required to develop NAP meant that the course had to remain unchanged for, say, 5-10 years before a major publications revision could be contemplated. Rogers summed up the situation when he said that NOP needed a 'good, confident trial' in itself.[21] However, by the late 1970s NAP had reached the contemplation of revision stage. In marked contrast to the original development, a number of useful evaluation studies were initiated involving the publishers, teachers, pupils, university education departments, higher education faculties with an interest in A-level physics, the Examining Boards and a cooperative venture with NAC on statistical thermodynamics.

It became clear that the NAP course was, quite naturally, beginning to look dated in places, common core A-level syllabus topics needed to be included, a more comprehensive Students' Guide was required to bolster student confidence and to include experiment details, summary notes and improved questions. Most of this preliminary work was initiated through the NCCT, in its embryonic form, and coordinated by an Advisory Committee. Consequently, a much tighter management structure was available for NAP than that for the earlier O-level Physics revision. Moreover, with Black and Ogborn being on hand at Chelsea their experience and hard-won lessons could be built into the revision, whilst at the same time allowing detailed planning and editing to be carried out independently by Harris. For example, in November 1980 the Advisory Committee report, written by Black, recommended that "....the revision [to NAP] will need at least one full-time coordinator; a part-timer will also be needed to deal mainly with new or drastically changed topics. Effort should be expended to select for these posts two people who can work together in close proximity because of the great benefit of frequent contact."[22] Clearly, the Joint Organizers for NAP were anxious to repeat their successful working processes. In the event Harris fulfilled the full-time role with the help of Wenham.

Despite Harris and Wenham's combined editorial efforts the published RNAP course was over-full when compared to NAP. Possible reasons were:

- inclusion of common core topics;
- substantially enlarged Unit A;
- inclusion of new Units G and I.

In the original NAP course Ogborn recalled that the team tried to choose topics that related to a theme, say Fields, and then to treat the physics deeply.[23] As a result, some 'traditional' physics topics (e.g. angular momentum) were left out. Perhaps these topics could have been included at the level of some traditional syllabuses by just, in Ogborn's terms, 'mentioning the name'.[24] A similar situation arose in the NAP revision with the common core topics.

It was strongly suggested to Harris that he include the whole of the large A-level core material in the revision, and these items were written into the new course in a thematic way rather than included merely as a traditional syllabus item. As a result the RNAP course became bloated.

Furthermore, the inevitable revision model, using teacher-writers working part-time (mostly spare time), and independently, meant that some Units remained over-full even after editing. The most obvious example was Unit A.

A further constraint emerged from the radical nature of NAP and the innovative character of the physicists and teachers involved in the course and they wanted to enhance these characteristics in the revision and to include new ideas. Ogborn is a prime example:

"My position is that we originally did fairly well by being radical and by trying to foresee what a course should be like for a decade ahead; we ought not to assume that all those answers will go on working for another decade, without looking hard at them first. So I'm not happy with a purely 'mend and infill' strategy taken for granted."[25]

Ogborn foresaw the need for a new kind of Unit on measurement, which dealt with sensitivity, resolution, response time and reproducibility of instruments. He hoped that such a Unit would revise and teach much of the content and at the same time address the criticisms related to accurate experimental work.

Harris and his Consultative Committee had to weigh up all these extra demands as well as maintain the 'traditions' built into the original course. Harris' dilemma is in marked contrast to the 'clean slate' inherited by Black and Ogborn, and is more in keeping with the situation felt by revisers of syllabuses for Examining Boards. There was the inertia of the ‘old’, or at least by now established, course to accommodate as well as the need to include new ideas. Too often the result of such pressures is a bloated course that is gradually whittled down to a manageable size.

Unfortunately, the relatively limited resources available for RNAP meant that school trials were not possible. While a complete trial of the whole new course could have provided information on timing and amount of course material, only those Unit editors based in schools were able to conduct limited trials using their own classes. Another problem was that for a full course trial pupils would have had to be entered for the NAP examination having used the draft revised materials. Clearly these pupils would have been at a disadvantage. So instead of school trials, expert advice was sought in judging the suitability of the revised course, and its length. In this the experts were found wanting.

Overall, it appears as though a set of curriculum materials in physics can accommodate one publication-led revision. If the revision span is ten years then it would be twenty years to a second revision with the physics being accreted and the course moving a long way from the original conception. As Harris suggested, at that point the Nuffield A-level Physics course needed to be reborn, with the project directors having the advantage, once again, of starting with a clean sheet, but with a plethora of ideas to build upon.[26]

The Nuffield Foundation's wish to associate their NFSTP initiatives with examination renewal, as well as content and method innovation, has led Young to suggest that they helped sustain the existing distinction between academic and non-academic science[27]. Within this limitation NAP's association with the Oxford and Cambridge Board and with the NCCT, did allow for the professional development of physics teachers and helped provide INSET for physics education, as well as maintaining a firm basis for discussions about revisions and examination changes.

Therefore, the association of NAP with these institutions enabled teachers to feel some reassurance, knowing that there were competent people attending to new issues as they arise. Furthermore, the teachers' professional development, put alongside distinctive NAP features such as investigations and interactive teaching methods helped extend NAP's influence both sideways into other A-level syllabuses and downwards into GCSE practical assessment, perhaps even into non-academic science courses. NAP was at least one curriculum development project which was not as 'fossilised' as depicted in Kingdon's analysis.[28]

In organizing this curriculum history to include the revision to Nuffield A-level Physics it has been possible to throw some light on the term *institutionalized curriculum renewal*. The emergence of such an institution, the NCCT, has uncovered the following defining characteristics:

- the name *Nuffield* associated with quality materials and long term stability;
- publishing experience and continuity;
- the reputations of the Trustees, Officers and project Organizers, and a repository of tenured expertise at Chelsea College;
- a continuous interaction with the Examining Boards that enabled the revised courses to be examined without extensive re-negotiation;
- a recognizable mode of working involving initiating projects, and providing advisory bodies for management and evaluation;
- development of curriculum materials for a national market in science, mathematics and technology over the whole age range 5-19;
- financial independence and related power to influence curriculum matters;

- close involvement with a university department;
- working relationship with parent Nuffield Foundation.

Within its fiduciary limits, the NCCT had a wide choice of possible curriculum activity and, importantly, it could respond quickly to external changes in education policy.

Another aspect of the continuing concern shown for the schools' curriculum, as exemplified by the work of the NCCT and Chelsea College, was the post-NFSTP growth in similar university based institutions. Examples include Stenhouse's Centre for Applied Research in Education (CARE) at the University of East Anglia, the Shell Centre for Mathematical Education at the University of Nottingham, the School Mathematics Project (SMP) based at the University of Southampton, and the York University based Salters Horners Physics and Salters Chemistry. Together with a growing interest within university departments of education, this expansion involved many more people in teaching, research and curriculum renewal, as well as providing, for example, chairs in science education. Research journals evolved to focus this diverse activity, often coordinated through the university bases. A good example is the journal *Studies in Science Education*, first published in 1974 and centralized at the Centre for Studies in Science and Mathematics Education, at Leeds University.

It would be wrong to suggest that the Nuffield Foundation's initiatives in 1961-62 was the only cause of this expansion in curriculum renewal institutions. Worldwide interest in education and the curriculum expanded rapidly in the 1960s, spawned by a complex range of factors: ideology, politics, economics, previous experience, educational theory, or simply fashion. Even so, Waring comments: "Considerable euphoria accompanied the launching of the first [NFSTP] science projects, and curriculum development became a growth industry."[29] The NFSTP and its gradual emergence as an independent curriculum renewal institution did provide a model for people in this 'industry' to use, amend, or even reject. In this sense the Foundation's initiatives did help to raise the level of research and experiment and promoted the allocation of greater resources to a wide range of institutions, some also involved in curriculum renewal. In this light Farrer-Brown's vision for university-based curriculum renewal and education research institutions, outlined in his Paper F.115/1, has been vindicated. He wrote, in 1961:

> "But if the Foundation's work is to be extended, it may perhaps be fruitful to embark on a general programme of educational research

> and experiment....If there is a scarcity of qualified research workers, perhaps the main aim should be to improve (or where necessary initiate) the research activities of university departments of education."[30]

It is clear that Farrer-Brown had something like the NCCT's role in mind even before the O-level Physics enterprise was launched.

After the initial euphoria of the first NFSTP publications, take-up was inevitably limited. Other agencies also experienced considerable variation in the implementation of centrally developed projects. Following the demise of the Schools Council in 1984, the centre-periphery model, and the consequent desirability of associating curriculum renewal with university based institutions, became questionable. The growth of alternative models, most notably the Secondary Science Curriculum Review, provided a lively opposition to the Nuffield methods of curriculum renewal. But locally based curriculum development, for example, can readily lead to a proliferation of courses and much duplication of effort, which may not be transferable into a wider, national context. Therefore, the *Nuffield* influence and methods remain a potent force in science education, based as they were on the institutionalized role of the NCCT.

In summary, the problems in the first NAP project forced the second project team, particularly Black and Ogborn, to expound their ideas clearly and widely, in order to produce a very successful curriculum development. In this they were supported by long term INSET provided by the Oxford and Cambridge Board examination meetings and by courses situated in university institutions, such as those organized by Archenhold and Chapman, at Leeds.

At the same time, the formation of the NCCT with its institutionalized curriculum renewal processes throws some light on long-term curriculum changes. Perhaps, NAP and its evolution provides a useful working model for change and the *Nuffield* model in general has been rejected too early by curriculum developers and theorists. Certainly, the history discussed here shows that the constraints and difficulties in the early part of NAP led it to practices which have much to recommend themselves in the more problematic circumstances of curriculum development after the National Curriculum.

INTRODUCTION - References and Notes

1. B.CHATWIN, Utz, Jonathan Cape(1988), p.119.

2. B.Z.PRESSEISEN, Unlearned Lessons. Current and Past Reforms for School Improvement, The Falmer Press (1985), p.2.

3. W.REID, Curriculum theory and curriculum change: What can we learn from history? J.Curriculum Studies, Vol.18, No.2, 1986, 159-166.

4. P.J.BLACK, see Chapter 3, reference 17.
J.M.OGBORN,see Chapter 3, reference 15.
P.J.KELLY, see Chapter 1, reference 160.
W.H.DOWDESWELL, see Chapter 1, reference 160.
E.H.COULSON, see Chapter 1, reference 19.
J.SPICE, see Chapter 1, reference 173.

5. P.H.TAYLOR (Ed.), Recent Developments in Curriculum Studies, NFER NELSON(1986), p.73.

6. W.REID, op.cit. 3, p.160.

7. W.E.MARSDEN, Historical approaches to curriculum study, History of Education Society Conference Papers - December 1978, Post-War Curriculum Development: An Historical Appraisal, p. 93. NB. This review of the 'early' literature helped to define the term 'curriculum history'

8. K.D.FULLER and D.D.MALVERN, One Don, One Beak - University pressure and curriculum development in the first Nuffield A-level physics project, British Journal of Educational Studies, Vol.32, No.1, 1986, 220-234. The quotation is found in the Editorial for Vol.32 on p.219.

9. E.SHILS, Tradition and Liberty: antinomy and interdependence, Ethics, Vol.LXVIII, 1958, pp.153-165.

10. I.F.GOODSON, Studying curriculum: towards a social constructionist perspective, J.Curriculum Studies, Vol.22, 1990, 299-312.

11. I.GOODSON, The Making of Curriculum: Collected Essays, The Falmer Press(1988).

12. T.EDWARDS, Curriculum matters, The Times Educational Supplement, 8 July 1988, p.26.

13. J.H.BADLEY was the founding Headmaster at Bedales from 1893 to 1935. Rogers and Badley conducted an active correspondence, especially in the periods when Rogers was living in the USA. It is apparent that Rogers held Badley in awe and that Badley's views on liberal co-education greatly influenced Rogers' attitudes. See: J.H.BADLEY, Memories and Reflections, George Allen and Unwin Ltd(1955).

14. A brief account of F.A.(Freddie) MEIER'S life and work is found in: K.D.FULLER, A Review of Nuffield A-level Physics with Particular Reference to the Historical Development and the Financial Aspects of the Project, unpublished M.Sc. dissertation, the University of Reading(1982), pp.8-11.

15. K.D.FULLER and D.D.MALVERN, op.cit. 8.

16. INSTITUTE OF PHYSICS EDUCATION GROUP, Physics Education Across the School Higher Education Interface, 21-23 March 1986, Christ's College, Cambridge, Conference Handbook p.17.

17. H.SILVER, Nothing but the past, or nothing but the present?, Times Higher Educational Supplement, 1 July 1977, p.17.

18. Ted WENHAM was involved in all stages of the developments of NOP and NAP and their revisions, although he was not officially on the NAP development teams. John LEWIS is the nearest person to have a full overview, see Chapter 1, reference 25.

19. Professor J.OGBORN interview with K.D.FULLER 15 February 1991.

20. R.WALKER, Nuffield Secondary Science in Curriculum Research and Development in Action, edited by L.STENHOUSE, Heinemann Educational Ltd.(1980), p.83.

21. P.J.KELLY, Curriculum Development and Curriculum Mechanism. An account of the Nuffield A-level Biology Project in relation to the concept of curriculum mechanism, unpublished Ph.D. thesis, University of London(1971), p.447.

22. L.COHEN, Educational Research Methods, in L.COHEN, J.THOMAS and L.MANION(Eds), Educational Research and Development in Britain 1970-1980, NFER Nelson(1982), pp.438-439.

23. P.J.BLACK, Pupils' attitudes to science, Studies in Science Education, Vol.4, 1977, 149-153.

24. M.WARING, Background to Nuffield Science, History of Education, Vol.8, No.3, 1979, 223-237.

25. M.D.SHIPMAN, D.BOLAM and D.R.JENKINS, Inside a curriculum project. A case study in the process of curriculum change, Methuen and Co.Ltd.(1974), p.x Preface.

26 I.F.GOODSON and R.WALKER, Biography, Identity and Schooling: Episodes in Educational Research, The Falmer Press(1991), p.111.

27. I.GOODSON, Subjects for Study: Aspects of a Social History of Curriculum, J.Curriculum Studies, Vol.15, 1983, 391-408.

28. R.INGLE and A.JENNINGS, Science in Schools: Which Way Now?, Heinemann Educational Books(1981), p.30.

29. G.McCULLOCH, E.JENKINS, D.LAYTON, Technological Revolution? The politics of school science and technology in England and Wales since 1945, The Falmer Press(1985), pp.104-105.

30. J.OGBORN, Modern physics curricula in higher education, Rep.Prog.Phys., Vol.42, 1979, 727-772.

31. M.WARING, Aspects of the dynamics of curriculum reform in secondary school science, unpublished Ph.D. thesis, Chelsea College, University of London(1975), p.15.

32. M.ERAUT, Nuffield Science, J.Curriculum Studies, Vol.11, 1979, 341-346.

CHAPTER ONE - REFERENCES and NOTES

Chapter 1 - Part I

1. Minutes of the 115th Meeting of the Trustees of the Nuffield Foundation, 8th December 1961, at Nuffield Lodge.

Nuffield Foundation Trustees: Sir Geoffrey Gibbs(Chairman), Sir Hector Hetherington (Vice-Chairman), Sir Frank Engledow, W.R.Gowers, Sir Alexander Todd and Dame Janet Vaughan.

Nuffield Foundation Officers: Dr.L.Farrer-Brown(Director), Mr.A.Becher, Brigadier C.Hurley, Dr.J.W.McAnuff and Mr.J.H.Owen.

2. ibid.

Sir (now Lord) Alexander TODD, Emeritus Professor of Organic Chemistry, University of Cambridge, born 1907, Master of Christ's College, Cambridge 1963 78, Nobel Prize for Chemistry 1957, Chairman of the Government Advisory Council on Scientific Policy 1952-64, Chairman of the Royal Commission on Medical Education 1965-68, Trustee of the Nuffield Foundation and Chairman of the Managing Trustees 1973-79. President of the Royal Society 1975. Chairman, House of Lords Select Committee on Science and Technology 1980.

3. D.LAYTON, Interpreters of Science: A History of the Association for Science Education, John Murray(1985), pp. 229-245.

4. Minutes of the 117th Meeting of the Trustees, Friday 16 February 1962, Nuffield Lodge. Minute iv.1304. McGill was seconded from the Scottish Education Department for a period of two or three years, with an increase in salary, travelling expenses, and the Foundation reimbursing the Department for his salary and a contribution of 15% of his salary towards superannuation rights.

DONALD McGILL studied physics at King's College, Newcastle-on-Tyne, and first taught physics in 1936 at Shipley, in Yorkshire. He became a Lecturer at the H.H.Wills Laboratory in Bristol (with Mott and Keohane) and was Senior Examiner at the Bristol Examinations Board. McGill was very interested in using examination questions to change quickly the style of teaching. He returned to school teaching at Bradford Grammar School in order to teach the understanding and skills that could be tested by a different style of examination. In 1959 he was appointed HMI in the SED and seconded to the NFSTP in 1962.

5. C.E.SWARTZ, "Strong and Weak Interactions". Swartz's acceptance speech for the 1987 Oersted Medal presented by the American Association of Physics Teachers, 30 January 1987. Am.J.Phys, Vol. 55, No.9,1987, 781-785.

6. B.T.W.JAMES, The contribution of The Institute of Physics to education and its influence thereon, unpublished M.Ed dissertation, University of London(1976).

7. Sir WILLIAM HUGGINS, The supreme importance of science to the industries of the country, which can be secured only through making science an essential part of all education, An address delivered at the Anniversary Meeting of the Royal Society, 1 December 1902, Royal Society Archives. Sir William Huggins, K.C.B., O.M., was President of the Royal Society from 1900 to 1905. Huggins speech recognised the 'wonder and delight' of science and stressed the need for elementary science taught practically with the aid of experiment.

More immediate to the formation of the NFSTP, the Royal Society set up, early in 1957, another committee to explore ways in which they might improve and extend the teaching of science in schools. They were anxious to find ways to increase the number of trained scientists and technicians, and to avoid early specialisation. Membership of a Science in Education Committee, set up by the Council of the Royal Society at its meeting on 17 January 1957: Sir T.Merton(Chairman), Lord Bridges, Sir L.Brown, Dr.M.L.Cartwright, Sir John Cockcroft, Dame Kathleen Lonsdale, Dr. Willis Jackson, Dr.B.N.Wallis, Professor F.G.Young.

8. INTERNATIONAL CONFERENCE ON PHYSICS EDUCATION, UNESCO House, Paris, 28 July - 4 August 1960, reported in Contemporary Physics, Vol. 2, 1960-61, p.69. This conference was organised by the Organisation for European Economic Cooperation (OEEC) and the International Union of Pure and Applied Physics with 100 delegates from 26 nations. The conference chairmen were Professor S.C.Brown(USA) and Mr.Norman Clarke(UK). Professor J.R.Zacharias(USA) and Dr.H.White(USA) presented the PSSC syllabus and programme. Dr.H.F.Boulind(UK) discussed examinations in physics.

9. BRITISH NATIONAL COMMITTEE FOR PHYSICS, Minutes of a meeting held on 26 January 1961, C/22(61). Royal Society Archive.

10. N.CLARKE to D.MARTIN, 1 December, 1961, Royal Society Archive.

The membership of the National Committee on Physics Education: Professor N.F.Mott, University of Cambridge(Chairman); Dr.N.Astbury, the British Ceramic Research Association; Sir Lawrence Bragg, Royal Institution; Professor C.C.Butler, Imperial College; Dr. J.Goodier, Eton College; Mr.B.Holmes, University of London Institute of Education; Mr. J.Lewis, Malvern College; Professor H.Lipson, Manchester College of Science and Technology; Dr.J.Topping, Brunel College of Technology; Professor D.Wright, University of Durham; Mr. N.Clarke, IPPS.

Mott, Lewis, Butler, Clarke, Topping and Goodier were all actively involved in the NFSTP. Biographical details of Mott are found in: Sir NEVILL MOTT, A Life in Science, Taylor and Francis(1986).

11. N.CLARKE to D.MARTIN, 5 February 1962. Royal Society Archive.

12. ibid.

13. R.W.CLARKE, A Biography of the Nuffield Foundation, Longman(1972), pp.164 170.

14. NUFFIELD FOUNDATION, Note of discussion between Mr. John Lewis, Senior Science Master at Malvern College, Mr. Norman Clarke, Assistant Secretary of the Institute of Physics, and the Director and Assistant Director, held on 30 October 1961. File EDU/52. Nuffield Foundation.

15. ibid.

16. N.CLARKE, op.cit. 11.

17. NATIONAL COMMITTEE ON PHYSICS EDUCATION, Minutes of a meeting on 13 February, 1962. Royal Society Archive.

18. Minutes of the 130th Meeting of the Nuffield Trustees, 4 October 1963, Nuffield Lodge. Paper F.130/27. Item No.31. Nuffield Foundation.

19. G.McCULLOCH, E.JENKINS, D.LAYTON: Technological Revolution? The Politics of School Science and Technology in England and Wales Since 1945, Falmer Press(1985), p.72.

See also:

M.WARING, Aspects of the Dynamics of Curriculum Reform in Secondary School Science, unpublished Ph.D. thesis, University of London(1975), pp.167-171.

20. G.McCULLOCH et al. op.cit. 19, p.101.

As a result of overlapping membership on these education sub-committees and the extent of the NFSTP initiatives, the Royal Society and the IPPS decided in July 1965 to form a Joint Education Committee.

21. PHYSICS EDUCATION started publication in May 1966, helped by a grant of £5,000 from the Nuffield Foundation. The first Consultant Editor, Professor K.W.Keohane, has written an article outlining the history of this journal: see K.KEOHANE, Physics Education - 21 years on, Phys.Educ.,22,1987, 142-146.

CHEMISTRY in EDUCATION began publication in January 1964 following a grant from the Nuffield Foundation of £10,000 for three years: see M.WARING, Aspects of the dynamics of Curriculum Reform in Secondary School Science, unpublished Ph.D thesis, University of London(1975), pp.170-171.

THE JOURNAL OF BIOLOGICAL EDUCATION began Publication in 1967 with J.D.Carthy as Editor. Two articles in the first edition originated from the NFSTP:

P.KELLY, Trends in Biological Education - an International Review. J.Bio.Educ. Vol 1,1967,1-12.

W.H.DOWDESWELL, The Nuffield Biology Project at O-level. J.Bio.Educ.Vol.1,1967,29-37.

22. G.McCULLOCH et al, op.cit. 19, pp.63-80.
M.WARING, op.cit. 19, pp.219-233.
D.LAYTON, op.cit. 3, pp.228-253.

23. D.LAYTON, op.cit. 3, pp.245-246.

24. BOULIND wrote to D.MARTIN at the Royal Society, requesting that the SMA be represented on Mott's Committee on Physics Education. In a curt reply Martin informed Boulind that Mott's Committee reported directly to the Royal Society and there would be few items of concern to the SMA. See:

D.C.MARTIN to N.CLARKE, 24 July 1962. In this letter Martin reports on a letter he received from SIR LAWRENCE BRAGG, who in turn had been approached by Dr.H.F.BOULIND. Royal Society Archive.

Dr.H.F.BOULIND was a lecturer in the Department of Education , University of Cambridge, SMA General Secretary from 1951-1955, and Chairman of the influential Science and Education Sub-Committee from 1956 to 1967. Eventually, Boulind worked energetically to help the NOP Organiser establish O-level physics examinations through the Oxford and Cambridge Schools Examination Board (acting on behalf of all Boards) and he devised the course 'Question Books', containing excellent questions for thinking and understanding.

25. B.E.WOOLNOUGH, Physics Teaching in Schools 1960-85: Of People, Policy and Power, the Falmer Press (1987). Details of John Lewis's education and interests have a special section in this book, on pp. 91-94. See also:

J.L.LEWIS, A Report on a Sabbatical Term, Nov.1961, printed for private distribution by Esso Petroleum Co.Ltd.

J.L.LEWIS, The Physical Science Study Committee: a survey of its publications, Contemporary Physics Vol.1, 1959-60, 248-252.

26. D.LAYTON, op.cit. 3, p.230.

27. M.ERAUT, Reviews - Nuffield Science, J.Curriculum Studies, 1979, Vol.11, No.4, 341-346.

A detailed analysis of the Industrial Fund is found in:

G.McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies of Science, Vol.18, 1988, 703-724.

G.McCULLOCH, Education for Leadership in the 1950s: The Ideology of Eric James, J.of Educational Administration History, Vol.21, 1989, 43-51.

28. D.LAYTON, op.cit. 3, p.230.

29. H.F.BOULIND, Atomic Energy and Education, SSR, March 1959, No.141, 331-337.

30. H.F.BOULIND, Conference on Science Curricula at the UNESCO Institute for Education, Hamburg, 22-27 October 1956, SSR, March 1957, No.135, 291-293.

31. M.WARING, op.cit. 19, p.161. Furthermore, in December 1961, just before the formation of the NFSTP, the Trustees of the Nuffield Foundation agreed a grant of £1000 to allow J.Lewis, the senior science master at Malvern College, to invite M.S. Smith, the physics master at King's College School, Wimbledon, and J.M.Osborne, the physics master at Westminster School, to spend a few weeks at Malvern, in development work on the teaching of modern physics.

32. K.CHAPMAN and E.COULSON, An enquiry into the conditions affecting science teaching in Grammar Schools, SSR., March 1954, No.126, 168-177.

THE FOUR ASSOCIATIONS, Provision and Maintenance of Laboratories in Grammar Schools, the results of a questionnaire issued by the SMA, AWST, NUT and JOINT FOUR, in a joint committee of the four secondary school associations:
SSR, June 1958, No.139, 438-446, and
SSR, June 1960, No.145, 461-473.

Membership of the Science and Education Sub-Committee (re-named Science Teaching Sub-Committee), April 1957: Dr.H.F.Boulind (physics); H.F.Broad (physics); E.H.Coulson (chemistry); W.H.Dowdeswell (biology), E.W.Moore (chemistry); H.P.Ramage (biology); and H.Tunley (physics). For further details see D.LAYTON, op.cit. 3, p.237.

33. THE NUFFIELD FOUNDATION, An informal discussion on the teaching of Biology in schools, 2 May 1962. A paper prepared for the 119th Meeting of the Trustees, 18 May 1962. Paper F.119/25 Item 39(b), EDU/52, Nuffield Foundation.

34. M.WARING, op.cit. 19, p.219.

35. D.LAYTON, op.cit. 3, p.238.

36. G.McCULLOCH et al, op.cit. 19, p.68.

37. PHYSICAL SCIENCE STUDY COMMITTEE (PSSC). In the mid 1950's a group of physics professors at MIT and Harvard, in the USA, examined the secondary school physics curriculum. Led by Professor Jerrold Zacharias, they concluded that school physics did not reflect the topics considered of greatest importance by professors of physics. In 1956, the National Science Foundation began to fund Zacharias' group, to produce ideas and curriculum materials for the 16-17 year-old high school students. The costs ran into tens of millions of dollars.

38. H.F.BOULIND, The Physical Science Study Committee. The Summer Institute Courses. Contemporary Physics, Vol.1, 1959-60, 307-312.

39. SUB-COMMITTEE ON THE TEACHING OF MODERN PHYSICAL SCIENCE (1959-1966):

Miss R.C.Barrow	County School for Girls, Reigate
N.Booth	HMI
Dr.H.F.Boulind	University Department of Education, Cambridge.
N.Clarke	Institute of Physics
Dr.L.R.B.Elton	Physics Dept., Battersea College of Technology
R.A.Faires	Isotope School, Wantage Research Lab., AERE.
Dr.J.Goodier	Eton College
M.J.Harrap	Whitgift School, Croydon.
J.L.Lewis(Chairman)	Malvern College
W.Llowarch	University of London Institute of Education.
V.J.Long	HMI
Miss K.M.Murphy	Colston Girls School, Bristol
J.M.Osborne	Westminster School
B.H.Parks	Isotope School, AERE
T.A.Peacocke	St.John's School, Leatherhead
Sister St.Joan of Arc	La Retraite High School, Bristol
M.S.Smith	King's College School, Wimbledon
E.W.Tapper	Institute of Education, University of Bristol
E.J.Wenham (Secretary)	City of Worcester Training College.

40. D.LAYTON, op cit. 3, p.239.

41. R.J.MONTGOMERY, Examinations: An account of their evolution as administrative devices in England, Longmans (1965), pp.131-171.

The Secondary School Examinations Council (SSEC) was first formed in 1917, to advise the Board of Education (later the Ministry of Education) on school examinations. The Chairman was appointed by the Ministry, with representatives from the examining bodies, the local authorities, teachers' associations and the universities. HMI attended as assessors but did not vote. SSEC approval was required before any new syllabus or examination could be implemented.

42. M.WARING, op.cit. 19, p.211.

43. D.LAYTON, op.cit. 3, p.240.
B.E.WOOLNOUGH, op.cit. 25, p.51.

44. R.A.R.TRICKER, The Sceptical Physicist, Contemporary Physics Vol.2, 1960-61, 21-30.

Dr. Tricker was a Staff Inspector in the Ministry of Education for 17 years. He completed a Natural Science Tripos at Cambridge in 1923 and was awarded his Ph.D. in 1926 for work on relativistic variation in electron mass.

45. Professor L.R.B.ELTON, interview with K.D.FULLER, 5 May 1988.

46. A.S.E., Pilot Scheme in Intermediate Physics. The Studley Experiment: Interim Report, ASE Bulletin No,9, April 1964, 17-23.
A.S.E.The Studley Experiment, ASE Bulletin No.14, September 1965, 32-38.

47. A.S.E.(1964), ibid., p.22.

48. R.A.BECHER to L.FARRER-BROWN, 4 February 1964, File EDU/52, CIV/52(d). Nuffield Foundation.

49. Sister ST.JOAN OF ARC, The Teaching of Modern Physics in Schools, Contemporary Physics, Vol.2, 1960, 403-408.
Sister St.Joan of Arc was educated at La Retraite High School, Bristol, and the University of Bristol. At the time of writing her report she was Senior Science Mistress at La Retraite High School.

50. B.E.WOOLNOUGH, op.cit. 25, p.89.

51. Minutes of the 115th Meeting of the Trustees of the Nuffield Foundation, Friday 8 December 1961, Item D, Curricula and teaching methods.

52. L.R.B.ELTON, Modern Physics in the Middle School: Study Group at Battersea College, Easter 1961, Elton Papers.

53. Sister ST.JOAN OF ARC, op.cit. 49.

54. L.R.B.ELTON, A Summing-up. Study Group on the teaching of modern physics in schools, 4-8 April 1961. Elton papers.

55. INTERIM REPORT: THE TEACHING OF MODERN PHYSICS. The Science Masters' Association and the Nuffield Foundation(1962).

56. D.McGILL AND R.A.BECHER to L.FARRER-BROWN, 1 June 1962, O-Level physics - Modern Physics Report, CIV/52, Nuffield Foundation.

57. R.A.BECHER to W.TAPPER, 30 November 1962, CIV/53. Nuffield Foundation.

58. D.LAYTON, op.cit. 3, p.240.

59. R.W.CLARKE, A Biography of the Nuffield Foundation, Longman Group, London(1972), p.170.

60. M.WARING, op.cit. 19, p.238.

61. A.J.MEE, HMI, to HMSCI Mr.BRUNTON, 5 January 1962, reporting on the Ministry's Science Panel meeting held on 4 January 1962. A carbon copy was sent to D.McGill, HMI. Wenham Papers.

62. R.W.CLARKE, op.cit. 59, p.170.

63. L.FARRER-BROWN, draft letter to the MINISTER OF EDUCATION, explaining the first twelve months' developments of the NFSTP, with a similar letter sent to the MINISTER FOR SCIENCE, July 1962, EDU/52. Nuffield Foundation.

64. Paper F.116/4 'O' level Physics Project, Minutes of the 116th Meeting of the Trustees of the Nuffield Foundation, 19th January 1962, Nuffield Lodge, Nuffield Foundation.

65. Paper F.117/10 Science Teaching, 'O' level Physics Project. Minutes of the 117th Meeting of the Trustees of the Nuffield Foundation,, 16th February 1962, Nuffield Lodge, Nuffield Foundation.

66. A.J.MEE to HMSCI Mr.BRUNTON, 5 January 1962, with a copy sent to Mr.D.McGill. Wenham Papers.

A.J.Mee, HMI for the Scottish Education Department, was responsible for the revision of the chemistry syllabuses in Scotland. He served on the Consultative Committees of the Nuffield 'O' and 'A' level projects.

J.S.Brunton was the Senior Chief Inspector for the Scottish Education Department. He served as an observer on the Schools Council.

67. ibid.

68. ibid.

69. ibid.

70. Professor E.M.ROGERS, communication with K.D.FULLER, 18 October 1986.
E.J.WENHAM, interview with K.D.FULLER, 4 August 1986.

71. B.E.WOOLNOUGH, op.cit. 25, p.89.

Examples of pragmatic HMI help in the NFSTP are, of course, V.J.Long, who Organized the first years of NAP, as well as being active in NOP; N.Booth, who sat on the Joint A-level Physical Science Consultative Committee; L.Smith, who paved the way for the NFSTP to encompass science for average to below average secondary school pupils (Newsom Science); and A.Mee, J.Brierley and S.Skillen, who served on the Consultative Committees for NOC and NOB.

72. B.E.WOOLNOUGH, op.cit. 25, p.189.

73. L.FARRER-BROWN, The teaching of Science and Mathematics, Paper F115/2, presented to the 115th Meeting of the Trustees of the Nuffield Foundation, 8 December 1961, Nuffield Lodge. Nuffield Foundation.

74. Derek MORRELL was educated at Keeble College, Oxford, and joined the Ministry of Education in 1947. He helped foster the Curriculum Study Group and became the first Joint Secretary of the Schools Council 1964-1966. Morrell and the other Ministry officers became crucial figures in the Government's Curriculum Study Group. The interaction between the Nuffield Foundation and the Curriculum Study Group in the early 1960s is not recorded in the literature and needs further research.

75. L.FARRER-BROWN, Nuffield Foundation Physics Enterprise, Cambridge Conference, 28-29 September 1962. Verbatim Reporting Service, High Holborn, London. Wenham Papers.

76. M.WARING, Social Pressures and Curriculum Innovation. A study of the Nuffield Foundation Science Teaching Project, Methuen(1979), pp.88-89.

77. M.WARING, op.cit. 19, pp.237-238.

78. L.R.B.ELTON, review of Social Pressures and Curriculum Innovation. A study of the Nuffield Foundation Science Teaching Project, Mary Waring, Methuen(1979), in the British Journal of Educational Studies, Vol.28, 1980, 158-159.

79. B.E.WOOLNOUGH, op.cit. 25, pp.101-102.

80. R.INGLE and A.JENNINGS, Science in Schools: Which Way Now?, Heinemann Educational Books(1981), p.23.

When the Nuffield O-level projects were firmly established the NFSTP published a paper by L.G.Smith and a small group of HMI, discussing possible science courses for the average and below average pupil. This paper recommended that Hilda MISSELBROOK be appointed to organize Nuffield Secondary Science. See:

Minutes of the 134th Meeting of the Trustees of the Nuffield Foundation, 20 March 1964, Paper F134/5, Nuffield Lodge.

THE SCHOOLS COUNCIL, Science for the Young School Leaver, Working Paper No.1, undated. This paper was published for the NFSTP.

81. C.P.SNOW, The Two Cultures and the Scientific Revolution. Cambridge University Press(1962). The term 'Two Cultures' was first defined in the New Statesman 6 October 1956 and a detailed history of the term's origin is found in:

R.BIENIEK, Evolution of the Two Cultures controversy, Am.J.Phys., Vol.49, 1981, 417-423.

82. D.LAYTON, op.cit. 3, p.245.

83. L.FARRER-BROWN, op.cit. 75.

84. M.YOUNG, The schooling of science, in G.WHITTY and M.YOUNG(Eds), Explorations in the Politics of School Knowledge, Nafferton Books(1976), pp.47-51.

85. G.McCULLOCH (1988), op.cit. 27, p.708.

86. B.E.WOOLNOUGH, op.cit. 25, p.239.

87. D.LAYTON, op.cit. 3, pp.243-248.
G.McCULLOCH et al, op.cit. 19, pp.70-77.
R.W.CLARKE, op.cit. 13, pp.169-172.
M.WARING, op.cit. 76, pp.75-78.

88. Notes of a Planning Committee of the Science and Education Committee, held at BARROW COURT, on Monday 25 August 1961 at 5p.m., EDU/52, Nuffield Foundation.

In attendance:

Physicists: V.J.Long, HMI; N.Clarke; H.Tunley; Professor H.Lipson; L.R.B.Elton; H.F.Boulind; E.W.Tapper; J.L.Lewis.

Chemists: D.G.Chisman; E.H.Coulson; Miss F.Eastwood; M.C.Brown; N.Booth, HMI.

These members attended the opening meeting on 25 August. Layton records that only one representative of the biology panel, W.H.Dowdeswell, attended the conference. Three additional members of the AWST were in attendance: Miss B.Ashton, Miss M.Going and Miss J.Ling. See D.LAYTON, op.cit. 3, pp.241-243.

89. Minutes of the Science and Education Committee (SMA), on Saturday 2 September 1961, 9.30am BARROW COURT, near Bristol. EDU/52, Nuffield Foundation.

On 30 September 1961 the SMA's new headquarters at Bateman Street, Cambridge, were officially opened. Sir Alexander Todd, President of the SMA in 1956, was an important guest. After the ceremony he had an informal talk with E.H.Coulson and D.G.Chisman, about the possibility of government intervention into science education. Todd thought it 'most unlikely' and instead suggested the Nuffield Foundation.

90. Minutes of the 115th Meeting of the Trustees of the Nuffield Foundation, 8 December 1961, Minute iv.1211, Nuffield Lodge. Nuffield Foundation.

91. NUFFIELD FOUNDATION SCIENCE TEACHING PROJECT. Financial review prepared by Professor K.W.KEOHANE, January 1967, in time for the Trustees 159th Meeting 17 February 1967, at Nuffield Lodge.Nuffield Foundation.

92. INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY, Minutes of a meeting of the Committee on Physics Education, 13 February 1962, item 3. Royal Society Archive.

93. Minutes of the 116th Meeting of the Trustees of the Nuffield Foundation, 19 January 1962, Paper F.116/4, Nuffield Lodge.

At the end of July 1962, Wilf MACE from King Edward VII Grammar School, Sheffield, and Cyril READ, Director of Education for the West Sussex County Council, joined the Physics Consultative Committee. Morrell, at the Ministry, had recommended Mace, and Mott worked with Read when establishing the University of Sussex. A few months earlier Sister St.Joan of Arc and Professor J.C.GUNN from Glasgow were included. Finally, in July 1963, Rev.R.G.WICKHAM, from Twyford School, Winchester, joined the Committee to help preparatory school teachers and pupils to use the first two years of the NOP materials. For details, see: R.WICKHAM, The Nuffield Foundation Science Teaching Project X: Science in Preparatory Schools, SSR, Vol.49, 1968, 349-356.

Chapter 1 - Part II

94. M.WARING, Background to Nuffield Physics, History of Education, 8, 1979, 223 237.

THE MINISTRY OF EDUCATION AND THE NUFFIELD FOUNDATION, The Teaching of Science and Mathematics: Nuffield Foundation to provide £250,000 for development. Press release, not for publication before 15.30 hours on Wednesday 4 April 1962, File EDU/52, Nuffield Foundation.

95. D.McGILL, Operational Approach to 'O' Grade Physics, paper presented at first Consultative Committee meeting, 15 May 1962. Wenham Papers.

CONSULTATIVE COMMITTEE, Minutes of a meeting [the first] of the Nuffield Foundation Physics Project Consultative Committee, held at Nuffield Lodge on Tuesday 15 May 1962, EDU/52, Nuffield Foundation.

Those present: N.F.Mott(Chairman), C.C.Butler, N.Clarke, L.Farrer-Brown, J.Lewis, D.McGill; apologies from R.V.Jones.

96. A.J.MEE, W.R.RITCHIE and S.SKILLEN, Science Education in Scotland, SSR, 48, 1967, 685-691.

97. CONSULTATIVE COMMITTEE, Minutes of the second meeting of the Nuffield Foundation Physics Project Consultative Committee, Nuffield Lodge, Tuesday 29 May 1962, EDU/52. Nuffield Foundation.

98. As an indication of the importance of this exposure to the universities, Mott's inimitable article On Teaching Quantum Phenomena proved to be so popular that the

NFSTP immediately went into private production. In time, the memoranda were published in the journal Contemporary Physics, Volumes 1 to 6, and in 1969 selected articles were reproduced together as a book "Sources of Physics Teaching: Part I", selected articles reprinted from Volumes 1 to 6 of CONTEMPORARY PHYSICS. Introduced by Professor Sir N.F.MOTT, FRS. Taylor and Francis Ltd (1969). Articles:

On Teaching Quantum Phenomena: PROFESSOR SIR NEVILL MOTT, F.R.S. Cavendish Professor of Experimental Physics, University of Cambridge

The Development of Quantum Theory: PROFESSOR R.E.PEIERLS, C.B.E., F.R.S. Wykeham Professor of Theoretical Physics, University of Oxford

Nuclei and Nuclear Reactions: PROFESSOR O.R.FRISCH, O.B.E., F.R.S. Jacksonian Professor of Physics, University of Cambridge

Large-scale Properties of Matter: Dr.DAVID TABOR, F.R.S. Reader in Physics, University of Cambridge

Introducing the Boltzmann Distribution: Dr.A.D.C.GRASSIE, School of Mathematical and Physical Sciences, University of Sussex, and DR.J.E.SPICE, Senior Science Master at Winchester College

Looking at Metals: a Lecture for Schools: Dr.J.W.MARTIN, Department of Metallurgy,University of Oxford

The Metallic State: Dr.A.H.COTTRELL, F.R.S., Chief Adviser(Studies), Cabinet Office. Formerly Goldsmith's Professor of Metallurgy, University of Cambridge

Time and Relativity: PROFESSOR O.R.FRISCH, O.B.E.,F.R.S., Jacksonian Professor of Physics, University of Cambridge

The Measurement of Time and Frequency: Dr.LOUIS ESSEN, O.B.E.,F.R.S., Deputy Chief Scientific Officer, Division of Quantum Metrology, National Physical Laboratory

Errors of Observation and Systematic Errors: Dr.P.VIGOUREUX, Senior Principal Scientific Officer, Division of Quantum Metrology, National Physical Laboratory

Mechanical and Electrical Oscillations. Transient and Alternating Electrical Currents: PROFESSOR C.W.OATLEY, Professor of Electrical Engineering, University of Cambridge.

Waves: PROFESSOR ERIC MENDOZA, University College of North Wales, Bangor

The Physical Basis of Newtonian Mechanics: PROFESSOR NORMAN FEATHER, F.R.S., Professor of Natural Philosophy, University of Edinburgh

A Short History of Measurement Standards at the National Physical Laboratory: DR.H.BARRELL, C.B.E., Senior Advisor to the Directorate, National Physical Laboratory

99. NFSTP, Cambridge Conference, meeting with physics team leaders and the Foundation, Friday 28 September 1962, 10:00 am. Wenham Papers.

Mr. J.H.Owen, the Nuffield Foundation's finance officer, reinforced the policy that the team leaders had considerable flexibility with their own finances, bearing in mind local conditions. This enlightened policy enabled team leaders to purchase equipment, arrange for technician help and quickly implement their teaching experiments. The team leaders' float was generously increased for reasonable requests. In consequence, the

Organizer and his team leaders were remarkably free from financial pressure. This does not mean to imply that there was no critical scrutiny of the accounts: "The view was taken that your group was 'living it up a bit' - it was the six Gaelic coffees which caught the eye!" (E.J.WENHAM to B.CHAPMAN, 23 June 1965. Wenham Papers.)

100. NFSTP, Physics Enterprise Newsletters 1 to 5. Numbers 1 to 3 were distributed during October - December 1962. Wenham Papers.

101. Verbatim Report on the second day - Saturday 29 September 1962 - of the Nuffield Foundation Physics Enterprise September Conference held at Hughes Hall, Cambridge. The Palantype Organisation Limited, 229-231 High Holborn, London. Wenham Papers, p.23.

102. W.RITCHIE, op.cit. 101, pp.30-31.

103. H.F.BOULIND, op.cit. 101, p.36.

104. E.J.WENHAM, op.cit. 101, p.57.
In an article Conceptual demands in the Nuffield O-level physics course M.SHAYER, SSR, Vol.54, 1972, 26-34, an assessment based on Piaget's conceptual stages is described. Shayer concludes that the Nuffield Physics Enterprise both knew about, and allowed for, conceptual development in children and this was attempted in a more conscious way than in the planning of the chemistry and biology projects.

105. B.E.WOOLNOUGH, op.cit. 25, p.103.

106. D.McGILL, lecture notes for September Conference, Friday 28 September 1962, 2.15pm. Wenham Papers.

107. L.FARRER-BROWN, op.cit. 101, p.54.

108. A review of the Nuffield O-level Physics publications, SSR, Vol.XLVIII, 1967, 559-563.

109. N.F.MOTT to D.McGILL, 2 October 1962. Wenham Papers.

110. Professor SIR RONALD NYHOLM, FRS.
Nyholm first came to the UK from Australia in 1947 as an ICI Fellow based at University College, London. He returned to the University of NSW, Sydney, in 1951 and was then appointed Professor of Inorganic Chemistry at University College in 1955, where he became Head of the Chemistry Department in 1963. From 1962-65 he was Chairman of the NOC Consultative Committee and Vice-Chairman of the Joint A-level Physical Sciences Consultative Committee. He was ASE President 1968-69 and helped launch the appeal to build ASE's headquarters in Hatfield. He was Moderator in Chemistry for the University of London Schools Examinations Board. Nyholm helped

establish Education in Chemistry in 1964 and for the first 4 years he chaired the Education Advisory Board.

111. Professor ERIC ROGERS. Eric Rogers was educated at Bedales School 1916-21 and, on graduating from Cambridge University, was a physics master at Clifton College. He returned to Bedales as housemaster and physics master in 1928 and, whilst there, married Janet Drummond, in 1930. He moved to Harvard University, then Charterhouse, before returning to the USA in 1937. After a number of appointments he became Professor of Physics at Princeton University in 1942. He was active in the PSSC Project before becoming NOP Organizer in 1963. He retired from Princeton in 1971 and helped carry out the revision to NOP in the period 1971-80.

112. E.M.ROGERS, Physics for the Inquiring Mind. The methods, nature and philosophy of physical science. Princeton University Press (1960).
E.M.ROGERS, Teaching Physics for the Inquiring Mind, Princeton University Press (1962).

113. CONSULTATIVE COMMITTEE, Minutes of the fifth meeting of the Nuffield Foundation Physics Enterprise, held at Nuffield Lodge, Friday 30 November 1962. Wenham Papers.

114. D.McGILL to E.J.WENHAM, 8 February 1963. Wenham Papers.

115. CONSULTATIVE COMMITTEE, Minutes of the sixth meeting of the Nuffield Foundation Physics Enterprise, held at Nuffield Lodge, Thursday 31 January 1963. Wenham Papers.

116. ibid.

117. P.WILLIAMS (D.McGILL'S secretary) to E.J.WENHAM, 15 February 1963. Wenham Papers.

118. B.E.WOOLNOUGH, op.cit. 25, p.96.

119. Minutes of the 127th Meeting of the Trustees of the Nuffield Foundation, 17 May 1963, Nuffield Lodge.

120. E.J.WENHAM, The Nuffield Foundation Science Teaching Project - III: Physics 11 16, SSR, Vol.48, 1967, 337-346.
TED WENHAM graduated from King's College, University of London, and during World War II held a commission in the RAF. After the War he became Senior Physics Master at Sevenoaks School and in 1953 was appointed Senior Lecturer in Physics at the City of Worcester Training College. He eventually became Head of the Science Department at Worcester, and retired as Vice-Principal.

121. Minutes of the 127th meeting of the Trustees of the Nuffield Foundation held on Friday 17 May 1963 at Nuffield Lodge.

122. E.J.WENHAM, interview with K.D.FULLER 4 August 1986.

123. B.E.WOOLNOUGH, op.cit. 25, pp.97-98.

124. B.E.WOOLNOUGH, op.cit. 25, p.98.

125. E.J.WENHAM, op.cit. 120, p.339.

126. E.M.ROGERS, Comments on McGill syllabus. Undated. Wenham Papers.(see Appendix III).

127. E.J.WENHAM, op. cit. 120, p.339.

128. E.M.ROGERS to E.J.WENHAM 13 August 1963. Wenham Papers.

129. G.McCULLOCH et al, op.cit. 19, pp. 102-3.

130. R.A.BECHER to H.F.BOULIND, 18 February 1964. Wenham Papers.

131. ibid.

132. NFSTP Physics Teacher's guide general introduction. Provisional version 1964-65, pp.39-56.

133. R.A.BECHER, Proposals to the Examining Boards and the SSEC for special Nuffield examinations in Physics, Chemistry and Biology, 11 March 1964, File EDU/52. Nuffield Foundation.

134. E.M.ROGERS to J.MADDOX, 20 January 1965. Wenham Papers.

135. LOUGHBOROUGH CONFERENCE Advisers and Area Co-ordinators in NOP, 18-26 August 1964.

Organizers and Associate Organizers: E.M.Rogers, J.L.Lewis, E.J.Wenham.

Area Co-ordinators: J.M.Osborne, Sister St.Joan of Arc (Bristol), V.J.Long(York),B.Chapman(York), C.L.Williams(East Anglia), E.W.Tapper(East Anglia), D.J.Alexander(London), A.Lipson(London), R.D.Harrison(Northumbria), R.C.Hardwick(Midlands), M.J.Elwell(Midlands).

136. R.A.BECHER to V.J.LONG, 4 March 1964. Nuffield Foundation.

137. R.MUNRO, quoted in The Nuffield Approach. A collection of comments, definitions, and interpretations compiled by Safari (Success and Failure in Recent

Innovation) in studying Nuffield Secondary Science, undated, Safari Project, Centre for Applied Research in Education, University of East Anglia.

138. NFSTP Notes of the Meeting of Area Co-ordinators at Mary Ward House, Monday 14 December 1964. Wenham Papers.

139. E.ROGERS to E.WENHAM, 8 April 1965. Wenham Papers.

140. A selection of articles dealing with NOP:
W.ARCHENHOLD, Nuffield Physics in Practice, Educ.in Sc. No.22, 1967, 21-24.
N.BOOTH, The Impact of Science Teaching Projects on Secondary Education, Educ.in Sc. No.63, 1975, 27-30.
D.CHILLINGWORTH, Is Nuffield Physics worth the money? Education, 3 March 1967, 426-432.
A.DUFF, 1000 lessons of Nuffield Physics, Educ.in Sc. No.18, 1966, 13-17.
L.ELTON, Review of the Nuffield Books, Phys.Educ. Vol 2, 1967, 292-294.
M.ERAUT, Nuffield Science, J.Curriculum Studies, Vol.11, 1979, 341-358.
R.HARRISON, Implementing Nuffield Physics - where do we start from?, SSR Vol.49, 1969, 568-569.
J.LEWIS, The Nuffield physics project, Phys.Bull., Vol.16, 1965, 81-94.
J.LEWIS, From Daniell cell to the apparatus kit, Phys.Educ., Vol.4, 1969, 257-263.
J.LEWIS, 16+ examinations for Nuffield Physics, Phys.Educ., Vol.16, 1981, 157-160.
J.LEWIS and G.FOXCROFT, The Experimental Approach in the Nuffield Physics Course, in Physics Teaching in Schools, Editor G.DELACOTE, Taylor and Francis Ltd.(1978).
J.MADDOX, The Future of the Nuffield Projects, Educ.in Sc., June 1966, 24-29.
J.MADDOX, The Nuffield Physics Project, Phys.Educ., Vol.1, 1966, 3-7.
E.M.ROGERS, The Grim Report on Nuffield Physics, Educ.in Sc. No.21, 1967, 43-45.
W.SHERRATT, Astronomical material in Nuffield O-level physics, Phys.Educ., Vol.13, 1978, 42-46.
D.TAWNEY, Physics during the First Three Years of Secondary School in England and Wales, in Physics Teaching in Schools. Editor G.DELACOTE, Taylor and Francis Ltd.(1978).
E.J.WENHAM, The Nuffield Foundation Science Teaching Project: Physics 11-16, SSR, Vol.48, 1967, 337-346.

141. The Times Educational Supplement, Nuffield Science Topics, 5 May 1967, pp. 1517-1524.

142. B.E.WOOLNOUGH, op. cit. 25, pp. 103-107.

143. B.E.WOOLNOUGH, Changes in Physics Teaching in England since 1960: The People, Policies and Power in Curriculum Administration, in Case Studies in Curriculum Administration History, H.HAFT and S.HOPMANN(Eds), p.133.

144. B.YOUNG to E.WENHAM, 12 October 1965. Wenham Papers.

145. REVISED NUFFIELD O-LEVEL PHYSICS

Rogers and Wenham agreed to divide the revision work, with Wenham taking the prime responsibility for Years 1 and 2 and Rogers for Years 3,4 and 5. However, they would both be involved in re-writing the materials for all five years. They visited schools, talked with physics teachers, some sixth-form pupils and young teachers in training. Further consultation with teachers was achieved through a Nuffield Spirit enquiry form, which asked about pupils experiencing 'wonder and delight' and 'intellectual satisfaction'. Earlier it had been agreed that the revision would not 'water down' the original O-level scheme in order to meet the changes brought about by the comprehensive schooling. Instead, Rogers and Wenham decided to introduce Pupils' Text books, which provided help with experiments, some discussion of the ideas in the course, as well as 'thinking questions' and 'progress questions'. The progress questions were added to provide a different and easier approach to understanding the course work and were a direct result of teacher pressure and the needs of the new school structure.

In the middle of all this activity, Eric Rogers' wife, whom he had met and married whilst a housemaster and physics teacher at Bedales School in 1930, died suddenly. Wenham recalled that at this point there was more than a year's delay in the revision process. Rogers and Wenham somehow managed to get the important Year 3 manuscripts to the publishers at the end of 1974 but production problems caused further delays and the books did not reach the schools until autumn 1976. The disruption of the NFSTP administration and financial provision which occurred throughout the 1970s, as described in Chapter 5, together with personnel problems, resulted in prorogation. Consequently, the remaining Revised NOP materials were gradually made available to schools over a four-year span, 1977-80. The publishers estimated that the delays cost the newly emerging NCCT about £250,000 in lost revenue. For published details see:

E.M.ROGERS, The Revision of Nuffield O-level Physics, Educ.in Sci., No.64, 1975, 14-16.

REVISED NUFFIELD PHYSICS, General Introduction, Longmans Group Ltd.(1977), pp.ix-x.

Chapter 1 - Part III

146. L.FARRER-BROWN to E.G.PEIRSON, Principal, City of Worcester Training College, 9 April 1963.

R.A.BECHER to E.J.WENHAM, 3 April 1963. Wenham Papers.

147. G.McCULLOCH et al, op.cit. 19, pp.104-105.

148. E.J.WENHAM to K.W.KEOHANE, 3 July 1967. Keohane Papers.
J.L.LEWIS to K.W.KEOHANE, 29 June 1967. Keohane Papers.
E.M.ROGERS reported in Minutes of the eleventh meeting of the Nuffield Foundation Physics Project Consultative Committee, held at Tavistock Hotel, 2.30pm on Thursday 25 February 1965. Wenham Papers.

149. Professor E.M.ROGERS, communication with K.D.FULLER, 16 October 1986.

150. E.J.WENHAM, op.cit. 122.

151. B.E.WOOLNOUGH, op.cit. 25, p.122.
G.McCULLOCH et al, op.cit. 19, p.73.

152. IPPS, Minutes of a meeting of the British Committee on Physics Education at 47 Belgrave Square, on 30 April 1962. Royal Society Archive.

153. UNIVERSITY OF LONDON, An appraisal of GCE examinations in chemistry of the University of London. 1964. Introduction by Professor R.S.NYHOLM.

154. Minutes of the 131st meeting of the Trustees of the Nuffield Foundation, held on 22 November 1963 at Nuffield Lodge.

155. E.M.ROGERS to G.E.FOXCROFT, Rugby School, undated. Wenham Papers.

156. R.S.NYHOLM to A.BECHER, 8 November 1963, EDU/52. Nuffield Foundation.

157. A.BECHER to R.S.NYHOLM, 11 November 1963, EDU/52, C.iv/52(d). Nuffield Foundation.

158. NUFFIELD TRUSTEES, Minutes of the 131st Meeting of the Trustees of the Nuffield Foundation, held on 22 November 1963 at Nuffield Lodge.

159. Minutes of the 132nd meeting of the Trustees of the Nuffield Foundation, held on Friday 17 January 1964 at Nuffield Lodge.
The financial allocation is recorded in the minutes of the 134th Trustees meeting, 20 March 1964.

160. Professor PETER KELLY started teaching biology in 1955 at East Ham Grammar School, London, and then moved to Bexley School, in Kent, as Head of Biology. In 1960 he was awarded a travel scholarship to the USA to study curriculum developments in biology, including BSCS. He was seconded full-time to the NFSTP in 1962 to join the NOB team, to deal especially with the Year 5 materials. He returned to Bexley for only one term, resigned and was appointed Joint Organizer of NAB in 1965, where he worked

for nearly a year on his own laying the foundation for the A-level project. In 1968 he joined Chelsea College as a Senior Lecturer and, in 1976, became a Professor of Biological Education. He moved to the University of Southampton's Faculty of Educational Studies in 1979 as Dean and Head of Department.

Professor 'BUNNY' W.H. DOWDESWELL graduated before World War II and in 1962, at the commencement of NOB, was Senior Science Master at Winchester College. He was active in the SMA. He worked with E.B.Ford at Oxford University on ecological genetics (butterfly and moths) and made an academically respected contribution to the field. At the completion of NOB he returned to Winchester part-time, and joined the NAB team as Joint Organizer. Upon completion of NAB he accepted a position as Professor of Education at the University of Bath and was the Director of the Nuffield Foundation's University Biology Project. He stayed at Bath until his retirement.

161. R.A.BECHER, Some notes on the NFSTP, 28 November 1963. Paper F 132/28 prepared for the Trustees 132nd meeting. Nuffield Foundation.

162. ibid.

The Nuffield Foundation found accommodation for the NFSTP in the basement of Mary Ward House, owned by the National Institute of Social Work Training and in Tavistock House South, London.

163. N.F.MOTT to R.A.BECHER, 22 January 1964. Keohane Papers.

At the time, John Maddox was 38 years old, with a chemistry degree from Oxford. He had worked in universities as both a theoretical chemist and physicist. In 1955 he joined The Guardian as the science correspondent. Maddox left the NFSTP in June 1966. In 1975 Maddox rejoined the staff at Nuffield Lodge as Director for the Nuffield Foundation.

164. N.F.MOTT to L.FARRER-BROWN, 19 February 1964. Keohane Papers.

165. N.F.MOTT to R.A.BECHER, 21 February 1964. Keohane Papers.

166. L.FARRER-BROWN to E.L.BRADBY, Principal, Saint Paul's College, Cheltenham, 18 March 1964. Wenham Papers.

167. J.MADDOX to E.J.WENHAM, 19 June 1964. Wenham Papers.

168. N.F.MOTT to R.J.BLIN-STOYLE, 13 February 1964. Keohane Papers.

169. R.J.BLIN-STOYLE to N.F. MOTT, 18 February 1964. Keohane Papers.

170. N.F.MOTT to H.F.HALLIWELL, 17 July 1964. Spice Papers.

171. Professor MOTT's interest in physical science A-level is shown in reference 170.

Professor NYHOLM's keenness in an integrated physical science A-level is quoted in R.A.BECHER to Professor MOTT, 30 December 1963, EDU/52: CIV/53. Nuffield Foundation.

172. J.E.SPICE, Sixth Form Science: a new proposal, Times Educational Supplement, 7 June 1963. Spice Papers.

173. Dr. JOHN SPICE studied physical chemistry at Oxford during World War II and from 1945-59 he was a lecturer at Liverpool University. From 1959-72 he was the Senior Chemistry Master at Winchester College, where over half his time was spent developing NAPS. From 1972-84 he was Staff Inspector of Science at the Inner London Education Authority.

174. J.SPICE, interview with K.D.FULLER, 12 July 1988.

175. OXFORD UNIVERSITY DEPARTMENT OF EDUCATION, Arts and Science Sides in the Sixth Form. A report to the Gulbenkian Foundation, 1960, p.36.

176. ibid. p.36.

177. UNIVERSITY OF BIRMINGHAM, Report of an enquiry into the suitability of the General Certificate of Education Advanced level Syllabuses in science as a preparation for direct entry into first degree courses in the Faculty of Science. September 1959.

This report was financed by the Gulbenkian Foundation.

178. G.R.NOAKES, Gulbenkian Foundation Reports, Contemporary Physics, Vol.I, 1959 60, 315-7.

179. UNIVERSITY OF BIRMINGHAM, op.cit. 177, p.F9.

180. SMA and AWST, Physics for Grammar Schools. Part II. Advanced Phase: Physics for future scientists. John Murray (1961).

181. OXFORD UNIVERSITY, op.cit. 175, p.36.

182. J.SPICE, op.cit. 174.

183. ibid.

184. R.A.BECHER to J.SPICE, 4 May 1964. Spice Papers.

The chemistry meeting was held at Nuffield Lodge on Monday 8 June 1964 at 12.30pm.

185. Minutes of Nuffield Foundation A-level teaching committee meeting at Caius College, 27-28 June 1964. Secretary A.D.C.GRASSIE. Spice Papers.

186. ibid.

187. V.J.LONG to R.A.BECHER, 7 May 1964. File NAP 1.

188. EM..ROGERS to R.A.BECHER, 21 August 1963. Wenham Papers.

189. R.S.NYHOLM to N.MOTT, 9 July 1964. Spice Papers.

190. J.SPICE, Chemistry and Physics, in New Movements in the Study and Teaching of Chemistry, D.J.DANIELS(Ed.), Temple Smith(1975), p.60.

191. R.S.NYHOLM to B.YOUNG, Director of the Nuffield Foundation, 20 January 1965. Keohane Papers.

192. R.S.NYHOLM, op.cit. 189.

193. A.GRASSIE, op.cit. 185.
The studies into thermodynamics were published:
A.D.C.GRASSIE; J.E.SPICE and A.GERRARD, Introducing the Boltzmann Distribution, Contemporary Physics, Vol.7, 1965, 81-102.
J.E.SPICE, Teaching Thermodynamics to Sixth-Formers, Educ.in Chem., January 1966, 22-36.

194. V.J.LONG to J.MADDOX, 18 October 1964. File NAP 1.

195. THE 'A' LEVEL PHYSICAL SCIENCES COMMITTEE, with Mott and Nyholm as co chairmen, held meetings on 19 October 1964, 7 December 1964 and 11 February 1965.

196. J.MADDOX to N.F.MOTT, 29 January 1965. Keohane Papers.

197. N.F.MOTT, R.S.NYHOLM and J.MADDOX, The development and organization of A-level courses in the physical sciences. Paper F/142/27 prepared for the Nuffield Trustees' meeting on Friday 19 February 1965, Nuffield Lodge.

198. J.MADDOX to B.YOUNG, 27 January 1965. Keohane Papers.

199. J.MADDOX to N.F.MOTT, 24 February 1965. Keohane Papers.

200. J.MADDOX to N.F.MOTT, 16 December 1964. Keohane Papers.

201. J.SPICE to R.S.NYHOLM, 7 March 1965. Spice Papers.

Spice, on the other hand, argued that the Nuffield O-level chemistry course could be open to criticism if Nuffield students had to take a special A-level. Halliwell's line of argument was not used by the physics and biology Organizers.

202. R.S.NYHOLM, Nuffield Science Project A level work. 26 February 1965. Spice Papers.

203. ibid.

204. N.BOOTH to J.SPICE, 15 February 1966. Spice Papers.

205. CONSULTATIVE COMMITTEE,Minutes of the tenth meeting of the Nuffield Foundation(O-level) Physics Project Consultative Committee, held at Mary Ward House, 2.30pm Monday 9 November 1964. Nuffield Foundation.

206. N.F.MOTT to J.MADDOX, 26 February 1965. Keohane Papers.

207. Professor GUNN, quoted in op.cit. 205.

208. J.MADDOX to V.J.LONG, 11 November 1964. File NAP 1.

209. ASE PHYSICAL SCIENCE COMMITTEE: (P = Physicist; C = Chemist)

Professor J.T.Allanson Department of Electronic and Electrical Engineering, The University, Birmingham.
Dr.W.Bolton (P)High Wycombe College of Technology and Art.
Mr.N.Booth (C)Her Majesty's Inspectorate.
Dr.H.F.Boulind (P)Department of Education, University of Cambridge.
Mrs.A.Bradshaw (P)City of London Girls' School (a physical science trials school).
Mr.D.G.Chisman (C)Science Education Officer, British Council.
Miss F.M.Eastwood (C)Godolphin and Latymer Girls' School.
Mr.H.F.Halliwell (C)Department of Education, University of Keele.
Professor D.J.E.Ingram (P)Department of Physics, University of Keele.
Miss N.Jackson (P)Dame Alice Harper School, Bedford.
Dr.R.Kempa (C)College of St.Mark and St.John, Chelsea.
Mr.H.R.Jones (C)Her Majesty's Inspectorate.
Mr.J.L.Lewis (P)Malvern College.
Dr.F.R.McKim (P)Marlborough College; a member of the Nuffield physical science group.
Mr.M.S.Smith (P)King's College School, Wimbledon.
Dr.J.E.Spice (C)Winchester College; Organiser of the Nuffield physical science group.
Mr.D.W.H.Tripp (C)Brighton, Hove and Sussex Grammar School (a physical science trials school).

Mr.H.Tunley (P)late of The Merchant Taylors' School, Great Crosby.
Miss M.Wilson (C)Prescot Girls' Grammar School.

A report was published: Physical Science as a VIth Form Subject, ASE Bulletin, No.14, September 1965, 16-32.

210. SCHOOLS COUNCIL, Conference on Sixth Form Science, held at Rutland Hall, University of Nottingham, from the evening of Thursday 18 March to midday on Saturday 20 March 1965.

The conference resulted in the publication of Schools Council Working Paper No.4 Science in the Sixth Form, HMSO(1966).

211. B.YOUNG, M.A., was appointed Director of the Nuffield Foundation in March 1964 in succession to FARRER-BROWN. Previous to this he was Headmaster of Charterhouse School.

212. Minutes of the A-level physical sciences committee meeting held at Mary Ward House on Monday 22 March 1965 at 10.30am. Spice Papers.

213. NFSTP POLICY STATEMENT, Physical Sciences at A-level, 30 March 1965.

The policy statement was widely distributed and appeared in the ASE Bulletin, No.14 September 1965.

The developments in the physical sciences were guided by the Joint Committee for Physical Sciences under Professor Sir Nevill Mott, FRS, as Chairman, and Professor R.S.Nyholm, FRS, as Vice Chairman. The membership of the committee was as follows:

Professor J.T.Allanson	Department of Electronic & Electrical Engineering, Birmingham University.
N.Booth, Esq.,	HMI
Professor C.C.Butler, FRS	Department of Physics, Imperial College of Science and Technology.
Dr.J.R.Garrood	Emmanuel College, Cambridge.
Dr.A.D.C.Grassie	Physics Building, Sussex University.
H.F.Halliwell, Esq.	Department of Education, Keele.
Miss D.M.Kett	Mary Datchelor Girls' School, SE5.
Professor J.Lewis	Department of Chemistry, Manchester University.
A.J.Mee, Esq.	Scottish Education Department.
Professor J.D.Millen	Department of Chemistry, University College, London.
E.S.Shire, Esq.	Cavendish Laboratory, Cambridge.
Dr.P.Sykes	University Chemical Laboratory, Cambridge.
E.W.Tapper, Esq.	Association for Science Education.

214. K.W.KEOHANE, Nuffield Foundation Science Teaching Projects, January 1967. A paper prepared for the 159th Nuffield Trustees' meeting held on Friday 17 February 1967. Nuffield Lodge.

215. Professor K.KEOHANE communication with K.D.FULLER, 6 April 1982. File NAP 1.

In April 1966 a reappraisal of the A-level Biological Science project was undertaken and a reduced budget of £98,900 was agreed. Thus there was a saving of £36,735 (£135,635 - £98,900) available for transfer to the three physical sciences. The costing of the three physical sciences was reassessed at £333,110.

The original finance of £155,610 plus the saving of £36,735 made a total of £192,345, hence there was a shortfall of £333,110 - £192,345 = £140,765. The Trustees agreed to transfer the £36,735 and allocate £140,765 at their 159th meeting, 17 February 1967.

216. K.W.KEOHANE, op.cit. 214.

Notes on some aspects of the other Nuffield A-level projects which influenced NAP

Nyholm's influence as Moderator of the London Board's GCE O-and A-level chemistry examinations was considerable. In December 1965, Nyholm and Maddox met the Secretaries of the Examinations Boards to organize the A-level trials examinations. At this time, the Chairman of the Secretaries was George Bruce, who had worked closely with Nyholm at the London Board. Bruce arranged that the A-level examinations in NAC, NAB and NAP would continue to be coordinated by the corresponding Nuffield O-level Board:

NAC AND NOC - University of London School Examinations Department.
NAP AND NOP - Oxford and Cambridge Schools Examination Board.
NAB AND NOB - Joint Matriculation Board.
NAPS - University of Cambridge Local Examinations Syndicate.

University members on the NAB Consultative Committee strongly urged Kelly to introduce project work into the A-level assessment scheme. Both NAB and NAPS set aside 40 periods, about 10% of total course time, to an extended practical project. This work was assessed by the teachers in the schools and moderated by external assessors in the Examining Boards. Moderators were not required to visit schools. Such assessment was a major innovation at the time, 1965. These projects were essentially investigational or constructional. NAP, of course, decided on a more limited remit, practical investigation, but which also used similar assessment procedures.

In organising the NAB trials Kelly and Maddox had to convince the headmasters, advisers and parents that suitable assurances were forthcoming from the universities and other higher education institutions. The A-level biologists, of course, were acting as trail blazers for all the A-level projects. So, early in the 'phase 1' NAB planning, Maddox approached the universities through the Committee of Vice-Chancellors and Principals of the Universities of the United Kingdom. His particular contact was Sir Robert Aitken, chairman of their Standing Conference on University Entrance (SCUE), and Vice-Chancellor at the University of Birmingham. Aitken found that the NFSTP proposals were received sympathetically but that his detailed request to the universities would require outline syllabuses. Eventually, on 8 February 1966, Aitken wrote to all the Vice-Chancellors and Principals seeking an assurance that A-level passes in NAB would be recognised for the purposes of university entrance. By April 1966, Kelly was able to list the vast majority of universities as willing to corroborate in the trials. Similar assurances were soon forthcoming for NAC and NAPS.

Furthermore, in order to gain the confidence of the universities and allow them to participate in consultations with the NFSTP, Maddox and, later, Keohane suggested to Aitken that a Liaison Committee be established between SCUE and the NFSTP. The Chairman was Professor Allanson. This Liaison Committee had a dramatic influence on NAP.

After the much-needed injection of extra funds into the NAC project Coulson set up working groups to include representatives from industry, schools, universities and technical colleges to create materials in: glasses, ceramics, polymers, metals, materials science. Many of the groups were set up in conjunction with NAPS and included ideas involving technological applications of chemical principles. Eventually, similar groups were created in NAP.

The NAB project is noted for the quantity and quality of the evaluative information received during the course of the school trials and examinations. At an early stage the organizers recognized the danger of depicting students as a simple 'input-output focus' of curriculum developments. The data which were obtained from students, particularly with regard to examinations and relations with higher education and employment, were valuable and in some schools students cooperated with teachers in devising improvements to parts of the course. After the trials the mass of evidence from the evaluation processes was applied to the reformulation of objectives and the final re-designing and re-writing of the scheme prior to the commercial production of the books, visual aids and equipment. Keohane was particularly keen that the NAP project should incorporate 'NAB style' evaluation. Unfortunately his efforts were wasted.

CHAPTER 2 - REFERENCES and NOTES

1. J.MADDOX to V.J.LONG, 11 May 1965. File NAP 1.

2. J.MADDOX to V.J.LONG, 9 February 1965. File NAP 1.

3. NUFFIELD FOUNDATION SCIENCE TEACHING PROJECT, Science Teaching Newsletter, June 1966.

4. V.J.LONG to J.MADDOX, 23 September 1965. File NAP 1.

5. E.J.WENHAM, The position as it exists, hand-written notes, February 1967. Wenham Papers.

6. V.J.LONG, General and special studies in science, a paper prepared for SCHOOLS COUNCIL Working Paper No.4 Science in the Sixth Form, HMSO(1966), pp.30-37.

7. V.J.LONG, A response to Professor Chambers' comments, 8 February 1967. Circular to the NAP Consultative Committee 16 February 1967. File NAP 1.

8. B.Z.PRESSEISEN, Unlearned lessons: Current and Past Reforms for School Improvement, The Falmer Press(1988), p.2.

9. NUFFIELD A-LEVEL PHYSICS PROJECT, The Malvern Meeting, 20-24 August 1965. Those in attendance:
N.C.Barford, Miss R.Barrow, B.R.Chapman, G.E.Foxcroft, A.D.C.Grassie, J.Goodier, D.W.Harding, R.D.Harrison, Sister St.Joan, J.L.Lewis, V.J.Long, F.R.McKim, J.Maddox, N.F.Mott, J.M.Osborne, M.S.Smith, E.J.Wenham.

10. V.J.LONG, The Nuffield Advanced Physics Project, 1965. File NAP 1.

11. V.J.LONG to J.MADDOX, 23 September 1965. File NAP 1.

12. SECOND A-LEVEL PHYSICS CONFERENCE, 29 October to 1 November 1965, held at the Council Room, Mary Ward House, London. Those in attendance:
Mrs.A.M.Bradshaw, B.J.Brinkworth, C.A.Nickless, D.P.Read, M.S.Smith, A.W.Trotter, Miss J.B.Tresise, A.Price, B.Chapman, C.V.Burridge, D.Harding, V.J.Long.

13. V.J.LONG to E.WENHAM, 30 January 1966. Wenham Papers.

14. F.McKIM to J.SPICE, 10 August 1966. Spice Papers.

15. V.J.LONG, Advanced School Physics, first thoughts as possible guide lines for team members, undated. File NAP 1.

16. E.WENHAM and J.OGBORN to V.J.LONG, 7 July 1966. Wenham Papers.

17. MANCHESTER UNIVERSITY PHYSICS DEPARTMENT, Views on A-level Physics courses, 3 February 1966. Wenham Papers.

18. J.MADDOX to V.J.LONG, 15 June 1966. File NAP 1.

19. J.T.ALLANSON, Replanning the divisions in school science, Phys.Educ.,Vol. 1, 1966, 129-133.

20. V.J.LONG to J.MADDOX, 17 June 1966. File NAP 1.

21. ibid.

22. V.J.LONG to B.CHAPMAN, 28 January 1967. This letter was also circulated to other members of the NAP team and to the Consultative Committee. File NAP 1.

23. V.J.LONG to K.KEOHANE, 11 August 1966. File NAP 1.

24. ibid.

25. V.J.LONG, op.cit. 20.

26. E.WENHAM to V.J.LONG, 13 March 1966. Wenham Papers.

27. K.W.KEOHANE to V.J.LONG, 15 December 1966. File NAP 1.

28. V.J.LONG to K.KEOHANE and NAP TEAM MEMBERS, 9 December 1966. File NAP 1.

29. I.B.FALLOWS to V.J.LONG, 18 January 1967. File NAP 1.

30. Miss A.JACKSON to V.J.LONG, 3 July 1966. File NAP 1.

31. V.J.LONG, op.cit. 28.

32. V.J.LONG to K.KEOHANE, 3 January 1967. Keohane Papers.

33. V.J.LONG, op.cit. 6.

34. E.WENHAM to V.J.LONG, 24 October 1966. Wenham Papers.

35. J.T.ALLANSON to K.KEOHANE, 28 October 1966. Keohane Papers.

36. K.W.KEOHANE, Extracts from the minutes of a meeting of the Liaison Committee between the Nuffield Foundation and the Committee of Vice-Chancellors on University Admission, 16 February 1967. File NAP 1.

37. R.CHAMBERS, Some comments on the Nuffield Advanced Level Teaching Project, 8 February 1967. File NAP 1.
J.T.ALLANSON, Memorandum from Professor J.T.Allanson to Physical Science Consultative Committee, 13 January 1967. File NAP 1.

38. V.J.LONG to LIAISON COMMITTEE MEMBERS, 28 February 1967. File NAP 1.

39. V.J.LONG to E.WENHAM, 5 February 1967. Wenham Papers.

40. NAP team correspondence:
B.CHAPMAN to K.KEOHANE, 30 January 1967. File NAP 1.
G.FOXCROFT to K.KEOHANE, 30 January 1967. File NAP 1.
R.HARRISON to K.KEOHANE, 31 January 1967. File NAP 1.
M.SMITH to K.KEOHANE, 3 February 1967. File NAP 1.
A.TROTTER to B.CHAPMAN, 23 February 1967. File NAP 1.

41. E.WENHAM to D.HARDING, 5 February 1967. Wenham Papers.

42. D.HARDING to K.KEOHANE, 2 February 1967. Keohane Papers.
There are a few references in the correspondence to suggest that the Nuffield Foundation had briefly considered abandoning its project in A-level Physics. Keohane, in particular, was against the idea, feeling that such an action would disrupt the NAPS team and generate poor publicity in the eyes of both universities and schools.

43. B.YOUNG to J.LEWIS, 3 February 1967. File EDU/53, Nuffield Foundation.

44. R.G.CHAMBERS, Some comments on the Nuffield Advanced level Teaching Project, H.H.Wills Physics Laboratory: University of Bristol, 8 February 1967. File NAP 1.

45. ibid.

46. E.WENHAM, Some notes on a meeting between members of the A-level team and three members of the Vice-Chancellors Liaison Committee, 14 February 1967. Wenham Papers.

47. N.F.MOTT to V.J.LONG, 21 February 1967. File NAP 1.

48. B.YOUNG to V.J.LONG, 27 February 1967. NAP 1.

49. E.J.WENHAM interview with K.D.FULLER 4 August 1986.

50. R.D.HARRISON, The Nuffield A-level Physics Project, 15 February 1967. File NAP 1.

51. G.McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies of Science, Vol.18, 1988, 703-724.

52. K.W.KEOHANE, Memorandum from Professor K.W.Keohane for Physical Sciences Consultative Committee, Action suggested on Physics, 13 January 1967. Keohane Papers.

53. K.KEOHANE to V.J.LONG, 22 February 1967. Keohane Papers.

54. J.R.CRELLIN, R.J.J.ORTON and D.A.TAWNEY, Present-day school physics syllabuses, Rep.Prog.Phys., Vol.42, 1979, 677-725.

55. V.J.LONG, Nuffield 'A' Physics. Index of Papers. 15 September 1966. Wenham Papers.

56. V.J.LONG to N.F.MOTT, 28 February 1967. File NAP 1.

57. P.J.BLACK, Pupils' attitudes to science, Studies in Science Education, Vol.4, 1977, 149-153.

CHAPTER 3 - REFERENCES AND NOTES

1. Professor KEVIN KEOHANE graduated from the University of Bristol and went on to gain his Ph.D. and a Lectureship in the Physics Department at the same University. Whilst there he worked with DONALD McGILL and DONALD SCOTT to set physics questions for the Bristol Schools Examining Board and to debate physics teaching in general. In 1965 he became Professor of Physics at the University of London (Chelsea) and soon after accepted the post of NFSTP Co-ordinator. He was appointed Professor of Science Education and Director of the Centre for Science Education, Chelsea College, in 1967. From 1976-86 he was Rector at the Roehampton Institute, London, and was awarded a CBE in 1976. He served as the Chairman of the NCCT.

2. CHELSEA COLLEGE of SCIENCE and TECHNOLOGY. In 1965 the college failed to obtain independent university status and so Chelsea set up negotiations with the University of London to be admitted as a School of the University. This status was formally established by Royal Charter on 22 December 1971 and the official title became Chelsea College. Chelsea College - a history, edited by Harold SILVER and S. John TEAGUE, Chelsea College, University of London (1977).

3. J. MADDOX to B. YOUNG, 11 February 1966. Keohane Papers.

4. ibid.

5. W.D. SCOTT (Nuffield Foundation finance officer) to J. MADDOX (newly appointed DIRECTOR of the Nuffield Foundation), 30 October 1975, EDU/52. Nuffield Foundation.

6. R.A. BECHER, Note of a discussion with Dr. Gavin and Professor Keohane on the plans of the Chelsea Science Teaching Centre on Friday, 28 October 1966. Nuffield Foundation.

7. NUFFIELD FOUNDATION TEACHING PROJECTS:

Language Teaching Material Project, Organiser Mr. A. Spicer, was based in York and worked in close association with the Language Centre at York University. The Schools Council extended the work of the Nuffield Project.

Cambridge School Classics Project was based initially at Philippa Fawcett College of Education and directed by Lawrence Stenhouse. It eventually moved to the University of East Anglia.

Programme in Linguistics and English Teaching was based at University College, London, under the Research Director, Professor M. Halliday and jointly financed by the Nuffield Foundation and the Schools Council.

8. B. YOUNG, Visit to United States and America, October 12 to November 6 1965. Paper F.65. 12/1 presented to the 149th Meeting of the Trustees of the Nuffield Foundation, held on 3 December 1965 at Nuffield Lodge.

9. NUFFIELD-CHELSEA CURRICULUM TRUST, Minutes of the 53rd meeting of the Management Committee held on 16 January 1985 at Chelsea College. NCCT Archive.

10. K. KEOHANE, Nuffield Foundation Science Teaching Projects, Paper 67.2/17 presented to the 159th Meeting of the Trustees of the Nuffield Foundation, held on 17 February 1967 at Nuffield Lodge.

11. SCIENCE TEACHING BUDGET

A large additional allocation was set aside by the Trustees:

i) £140,765 for the development of the three A-level courses in physical sciences, including the extra cost of the redeemed physics project of about £27,500.

ii) £72,250 for the Co-ordinator and his team and of the Continuation Groups.

iii) £19,753 for O-level project deficits and for strengthening the Combined Science project.

12. NUFFIELD TRUSTEES, op. cit. 10.

13. E.J. WENHAM interview with K.D. FULLER 4 August 1986.

14. B. YOUNG to V.J. LONG, 27 February 1967. File NAP 1.

15. Professor JON OGBORN was a physics teacher at the Roan School, Blackheath, London, and in 1966 was appointed to the Worcester College of Education, primarily to organise in service teacher training. In 1967 he was seconded full time to the NFSTP as Joint Organizer for the NAP Project and was transferred to Chelsea College in 1968 to complete the final write-up of the NPA materials. In 1970 he was made a Senior Research Fellow at Chelsea College, and, in 1977, was promoted to Reader. In January 1984 he was appointed as Professor of Science Education at the University of London Institute of Education. He went on to become Director of the Post-16 Initiative at the Institute of Physics and Professor of Science Education at the University of Sussex.

16. E.J. WENHAM, op.cit. 13.

17. PROFESSOR P.J. BLACK, interview with K.D. FULLER 4 November 1988.

Professor PAUL BLACK graduated from Manchester University and obtained a doctorate from the Cavendish Laboratory, Cambridge. He was a Lecturer in the

Department of Physics, University of Birmingham, from 1956-76, and in 1966 was appointed Reader in Crystal Physics. In 1974 he became Professor of Physics (Science Education) before moving to Chelsea in 1976 as Professor of Science Education, and Head of the Centre for Science and Mathematics Education. In 1985 he became Head of the Centre for Educational Studies, King's College (KQC), London, and in 1989 was appointed Deputy Chairman of the National Curriculum Council. He is now retired as professor emiritus.

18. P.J. BLACK, University Examinations. A paper prepared for the Institute of Physics and Physical Society Education Group - Examinations Study Group, 6 December 1966. This paper was eventually published in Phys. Educ., Vol.3, 1968, 93-99.

19. P.J. BLACK, N.A. DYSON and D.A. O'CONNOR, Group Studies, Phys. Educ., Vol.3, 1968, 289-293.

20. Professor P. BLACK interview with K.D. FULLER, 4 November 1988.

21. K.W. KEOHANE to P.J. BLACK, 23 February 1967. Keohane Papers.

22. K.W. KEOHANE to R.A. BECHER, 15 March 1967. Keohane Papers.

23. NFSTP, Meeting to discuss the A-level physics project, Russell Hotel, London, 17 March 1967. Those present: Professor Mott, Professor Keohane, Dr. P. Black, J. Ogborn, A. Trotter, M. Harrap, G. Foxcroft, Dr. R. Longhurst, Dr. F. McKim.

24. Professor P. BLACK, op.cit. 20.

25. P.J. BLACK, The engineering and the humanity of science education, Inaugural Lecture 13, December 1977, Chelsea College (1980).

26. P.J. BLACK and J .M. OGBORN, NFSTP: Advanced Level Physics Section, Education in Science, April 1968, 44-49.

P.J. BLACK and J.M. OGBORN, The Nuffield Advanced Physics Course, Physics Bulletin, 21, 1970, 301-303.

P.J. BLACK and J. OGBORN, The Nuffield Physicist in the university, Phys. Educ., 7,1972. 66-70.

J.L. LEWIS (Ed.), Teaching School Physics - a UNESCO Source Book, Penguin Books Ltd. (1972)

G.E. FOXCROFT, Electronics in the Nuffield advanced physics course, Phys. Educ., 7, 1972, 14-20.

G.E. FOXCROFT, From levers to computers: Recent Advances in the Teaching of Physics, Proc. Roy. Instn. Gt. Br., 48, 1975, 157-171.

J.L. LEWIS, A Nuffield view of Physics, Phys. Educ., March 1977, 70-73.

A.W. TROTTER, 'It's not like that', Phys. Educ., 13, 1980, p.65.

27. J. OGBORN, Decisions in curriculum development - a personal view, Phys. Educ., 13, 1978, 11-18.

28. J. OGBORN to K. KEOHANE, 14 July 1967. Keohane Papers.

Black and Ogborn met Dick Long on 8 August 1967 to discuss the future of NAP. Long agreed to look after trial schools in the York area. Moreover, in June 1966, the Nuffield Foundation, in collaboration with the Ministry of Overseas Development, set up a Council for Curriculum Renewal and Educational Development (CREDO) to help emerging countries with their own curriculum development. The work consisted of passing on information by providing British experts and training facilities. On his retirement from the NFSTP Dick Long worked closely with Gordon van Praagh on the development of physics in East Africa: see G. VAN PRAAGH, Seeing It Through. Travels of a Science Teacher, Frognal Publishers (1988), West Sussex, pp.109-122.

After Dick Long's resignation ROGER HARRISON became the Editor of Nuffield Advanced Science: Book of Data, and BRYAN CHAPMAN helped with NAP trials in schools in the Yorkshire area and, importantly, set up NAP courses for physics teachers at the University of Leeds. TED WENHAM took over some of Jon Ogborn's duties at Worcester and continued to give advice and guidance about NAP.

29. Professor P. BLACK, op. cit. 20.

30. ibid.

31. M. PLASKOW (Ed.), Life and Death of the Schools Council, The Falmer Press (1985).

32. Professor J. OGBORN interview with K.D. FULLER 15 February 1991.

33. R.D. HARRISON, Some thoughts after the Liaison Committee Meeting on 15 February 1967. File NAP 1.

34. P.J. BLACK and J.M. OGBORN, The Nuffield Advanced Physics Course, Phys. Bull., 21, 1970, 301-303.

35. Professor P. BLACK, op. cit. 20.

36. R.G. CHAMBERS, Some comments on the Nuffield Advanced Level Teaching Project, W.H. Wills Physics Laboratory: University of Bristol, 8 February 1967. File NAP 1.
37. C.A. TAYLOR, quoted in R.G. CAWTHORNE, Nuffield Advanced Physics, Phys. Bull., 21, 1970, p.564.

38. NFSTP, P-GEN-1 Advanced level physics - Progress Report for Consultative Committee Meeting on 1 December 1967.

This paper contained organization details, first estimates for the equipment costs (£1000 for two years if schools were already equipped with O-level apparatus), a course plan, and details of working parties set up between university and school physics teachers.

NFSTP, P-GEN-2 Advanced level physics section.

Tentative course sequence at Nov.-Dec. 1967 for the information of the Consultative Committee. See P-GEN-5

NFSTP, P-GEN-3 Introduction to the work of the Physics section, November 1967. This general paper was eventually published in Education in Science, April 1968, 44-49.

NFSTP, P-GEN-4 Advanced level Physics, November 1967.

This paper was distributed to universities and other institutions of higher education with an interest in A-level physics. The paper evolved from Black and Ogborn's detailed presentation to the SCUE Liaison Committee on 27 September 1967.

NFSTP, P-GEN-5 Outline proposals for A-level physics course, January 1968.

This paper amplified, modified and replaced P-GEN-2. In general terms the course sequence given in this paper is the published course. Trials experience suggested that 'Reactive circuits and electronics' in the second year should replace 'Electromagnestism and Relativity' in the first year of the course.

39. E.J. WENHAM, op. cit. 13.

40. NFSTP, P-GEN-1 Advanced level physics - Progress Report for Consultative Committee Meeting on 1 December 1967. An unpublished report for the NFSTP.

41. NFSTP, Minutes of the Joint Physical Sciences Consultative Committee, 15 May 1967 at the Russell Hotel, London.
42. NFSTP, Advanced level physics. A paper prepared for the information of the Liaison Committee of the Standing Conference on University Entrance, 27 September 1967.

43. NFSTP, P-GEN-4. Advanced level Physics, November 1967.

44. Professor P. BLACK, op. cit. 20.

Black and Ogborn called on members both before and after meetings to seek their advice and criticism. For example in Thermodynamics (Unit 9) they arranged for a small group of university physicists to look at the work to see if it was theoretically valid.

45. P.J. BLACK and J.M. OGBORN, op. cit. 34, p.301.

46. E.M. ROGERS, Teaching Physics for the Inquiring Mind. Princeton University Press (1962), p.17.

47. Professor J. OGBORN, op. cit. 32.

48. V.J. LONG, A response to Professor Chamber's comments 8 February 1967. Circular to the NAP Consultative Committee - 16 February 1967. File NAP 1.

49. M. HARRAP to P. BLACK, 10 July 1967. File NAP 1.

50. P.J. BLACK and J.M. OGBORN [P-GEN-1], op.cit. 40.

51. J. OGBORN, op.cit. 27, p.13.

52. J.L. LEWIS, A Nuffield view of physics, Phys. Educ., 12, 1977, 70-73.

53. P.J. BLACK and J.M. OGBORN, op.cit. 34, p.301.

54. NUFFIELD ADVANCED SCIENCE, Physics Teachers' handbook, Chapter 3 pp.25-34, Penguin Books Ltd. (1971)

55. J. OGBORN, op. cit. 27, p.15.

56. ibid. p.12.

57. Professor P. BLACK interview with K.D. FULLER, 28 October 1981.
The first NAP Organizer, Dick Long, had originally used 16 schools in his preliminary trials, held during 1966-67. Long had used similar geographical groupings. However, only 7 of these schools were included in the first 25 trials schools selected by Black and Ogborn.

58. P.J. BLACK and J.M. OGBORN, Nuffield Advanced Physics - report to Consultative Committee, November 1969.

59. Professor J. OGBORN, op.cit. 32.

60. J. OGBORN. op. cit. 27, p.15.

61. ibid. p.16.

62. Professor P. BLACK, op. cit. 57.

63. T.M. AULD, interview with K.D. FULLER, 7 August 1981.

64. G. McCULLOCH, E. JENKINS, D. LAYTON, Technological Revolution? The Politics of School Science and Technology in England and Wales Since 1945, The Falmer Press (1985), p.6.

65. G. McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies in Science, 18, 1988, 703-724.

66. M. YOUNG, The Schooling of Science, found in G. WHITTY and M. YOUNG (Eds.), Explorations in the politics of School Knowledge, Nafferton Books (1976).

67. M. YOUNG, ibid. p.50.

68. R.A. SPARKES, Not all of us are Jeremiahs, Phys. Bull., 26, 1975, p.157.

69. A.L. MANSELL. During 1967, the Charter Consolidated Company Limited made available a sum of money to help with research into the recruitment of scientists into industry. These funds enabled Dr. Mansell to be seconded from his post of Senior Lecturer in Physical Chemistry at the Hatfield College of Technology. At the completion of the Nuffield A-level Science projects he remained on the teaching staff at Chelsea College.

70. A.L. MANSELL and G. VAN PRAAGH, Applied Science in the Nuffield A-level Chemistry Project, Chemistry and Industry, December 2, 1967, 2042-2043.

71. D.A. TAWNEY, Technology in the Nuffield Advanced Sciences, SSR, 54, 1972, 365-371.

72. J. OGBORN, op. cit.27.

73. P.R. LAWTON, On-going Evaluation of the Nuffield Advanced Physics Project - summary of the developments to October 1969, Keohane Papers.

74. Professor P. BLACK, op. cit. 20.

75. J.R.L. SWAIN, Evaluation studies on the Nuffield Physical Science Course, unpublished Ph.D. thesis, University of London, Chelsea College (1977), pp.42-44.

76. J. OGBORN and P. BLACK to K. KEOHANE, Cost of Draft Publications in Year Sept. 1969 1970 and later. Undated. Keohane Papers.

77. Professor P. BLACK, op. cit. 20.

78. Professor J. OGBORN, op. cit. 32.

79. J. OGBORN. The value of analysis of students' comments, found in W.K.D. MORGAN, The Nuffield A-level Project: A Study of the opinions of a sample of the pupils following the course in physics, M.Ed. dissertation, University of London (1971), pp.134-136.

80. ibid.

81. P.J. BLACK and J. OGBORN. The Nuffield physicist in the university, Phys. Educ., 7, 1972, 66-70.

82. Professor K. KEOHANE communication with K.D. FULLER 6 April 1982. File NAP 1.

83. OXFORD and CAMBRIDGE SCHOOLS EXAMINATION BOARD. Nuffield Advanced Level Physics. Report of a meeting in Cambridge on 26 January 1967 between Mr. Long, Mr. Harding, Mr. Chapman, Dr. Boulind, Mr. McKenzie and Mr. King. A.E.E. McKenzie was the Board's Secretary and H.F. King the Assistant Secretary. The meeting agreed that the papers would be a multiple-choice test and a 3-hour essay type paper. Unfortunately McKenzie died on 18 September 1969 and this interrupted the smooth development of the NAP examination negotiations with Paul Black and his team.

84. Professor P. BLACK, op. cit. 20.

85. P.J. BLACK and J.M. OGBORN, The Nuffield A-level physics examination, Phys. Educ., Vol.12, 1977, 12-16.

86. NFSTP Nuffield Advanced Physics. Report to the Consultative Committee, November 1969. The first trial examination in 1970 produced good results for the trials candidates with a mark distribution very close to the Oxford and Cambridge Board's usual results. Wilf Llowarch acted as the Board's Awarder and agreement was readily reached on grade borderlines.

87. Professor P. BLACK, op. cit. 20.

88. P. BLACK to Mrs. (Dr.) B.G. FREASER, 16 November 1971. Keohane Papers.

89. H.F. KING to P. BLACK, 10 December 1971. KEOHANE PAPERS.

90. B. YOUNG to K. KEOHANE, 4 August 1966, EDU/52. Nuffield Foundation.

91. H.F. KING, op. cit. 89.

The costing of the first two years of the NAP examination:

	1970	1971
Candidates	447	1091
Fees	£ 848	£2116
Expenditure	£1513	£3107
Deficit	£ 665	£ 991

The Board received £1200 from the Nuffield Foundation to offset the two years of deficit. For 3000 candidates the income at 1971 prices was estimated at £6,125 and the expenditure £6,175.

92. Professor P. BLACK, op. cit. 20.

93. C. GIPPS, A Critique of the APU found in P. RAGGART and G. WEINER (Eds.), Curriculum and Assessment: some policy issues, The Open University and Pergamon Press (1985).

94. NATIONAL CURRICULUM, Task Group on Assessment and Testing, A Report, DES (1987).

95. R. LOCK, A history of practical work in school science and its assessment, 1860-1986, SSR, 70, 1988, 115-119.

96. P. HALSEY to K. KEOHANE, 7 September 1970. Keohane Papers.

97. Professor P. BLACK, op.cit. 20.

98. J. OGBORN to K. KEOHANE, 19 September 1967, Keohane Papers.

99. Professor P. BLACK, op. cit. 20.

The Physics Teachers' Handbook, Nuffield Advanced Science, Penguin Books (1971) lists five teachers involved in the Pilot Trial: N. Belham, Worcester Grammar School for Girls; J. Crook, Bishop Vesey's School; M. East, King's School, Worcester; G. Foxcroft, Rugby School; C. Grant Dixon, Grammar School, Ross-on-Wye. Full details of individual investigations are found on pages 103-125 of the Teacher's handbook. In January 1970, Black and Ogborn sent to trials schools a first draft of these ideas. Assessment details had not been finalized and criteria were suggested from a NAPS paper. Appendices were attached giving possible examples and some detailed Case Histories from the pilot trial.

100. P.J. BLACK and J.M. OGBORN. The Nuffield Advanced Physics Course. Phys. Bull., 21, 1970, 301-303.

101. A.W. TROTTER, It's not like that, Phys. Educ., 15, 1980, p.65.

A.W. TROTTER, Project Work in Physics Education, in The Role of the Laboratory in Physics Education, edited by J.G. JONES and J.L. LEWIS, John Goodman and Sons (1978).

Bill Trotter died on 1 Mary 1981 and an appreciation of his life and work appears in Phys. Educ. 16, 1981, 194-195. 'Trotter Prizes' were awarded annually to students who submitted particularly good investigations.

102. T. SANDFORD, Investigation in action, Phys. Educ., 23, 1988, 341-344.

R. JAKEWAYS, Assessment of A-level physics (Nuffield) investigations, Phys. Educ., 21, 1986, 212-216.

103. K.D. FULLER, Laser Lissajous figures, in Physics Experiments and Projects for Students, Vol.1, edited by C. ISENBERG and S. CHOMET, Newman-Hemisphere (1985), pp.67-68.

104. K. DOBSON, Still investigating: twenty years of Nuffield A-level Physics investigations, Phys. Educ., 23, 1988, 337-340.

105. SCHOOLS COUNCIL Science Committee and Second Examinations Committee. Note of a meeting between Professor Keohane, representatives from two GCE Examining Boards and representatives from Science Committee held on Tuesday, 25 February 1969 to consider the part played by A-level projects in A-level science courses and the problems of their assessment. Keohane Papers.

Present at Meeting:

Mr. E.J. Machin (Chairman); Dr. M. Ashby; Mr. R. Christopher (The Joint Matriculation Board); Mr. E.H. Couison; Dr. J. Harvey; Mr. P. Kelly; Professor K.W. Keohane; Mrs. R. Speirs; Mr. T. S. Wyatt (University of Cambridge Local Examinations Syndicate).

Council Staff:

H.M.I. Dr. H. Jones; H.M.I. Mr. G.J. Neal; Mr. W.G. Easeman; Mr. A.M. Mitchell (Specialist Secretary).

106. R. SIBSON to K. KEOHANE, 28 May 1970. Keohane Papers.

Robert Sibson was a Joint Secretary at the Schools Council from 1966-1973 and a member of HMI. In 1960 the Beloe Report recommended a new examination for pupils unsuited to GCE O-levels. The first Certificate of Secondary Education (CSE) was conducted in 1965 and a CSE grade 1 was equated to a GCE O-level pass.

107. OXFORD AND CAMBRIDGE SCHOOLS EXAMINATION BOARD

Physics (Nuffield) at Advanced level 1991. Investigations 9661/6. Notes and instructions for Assessment.

108. A.D.C. PETERSON, The Future of the Sixth Form, Routledge and Kegan Paul (1973), p.79.

109. SCHOOLS COUNCIL GCE COMMITTEE, The curricular possibilities of a pattern of sixth form work based on major courses, minor courses and general studies , Memorandum by a group of H.M. Inspectors, GCE Paper No.11, undated. Spice Papers.

110. STANDING CONFERENCE ON UNIVERSITY ENTRANCE (SCUE), Minutes of the seventh meeting of the Standing Conference held in the University of London Senate House, Thursday, 28 September 1967. Spice Papers.

A brief history of the consultation between SCUE and the Schools Council appears in these minutes. As a result of SCHOOLS COUNCIL Working Paper No.5, Sixth-Form Curriculum and Examinations (1966), SCUE and the Schools Council reached agreement in SCHOOLS COUNCIL Working Paper No.16, Some Further Proposals for Sixth-Form Work (1967), to broaden the sixth form curriculum and leave specialization until as late as possible. Working Parties were set up to extend this work and published: Working Paper No.45, 16-19 Growth and Response, 1: Curricular Bases (1972) and Working Paper No.46, Growth and Response, 2: Examination Structures (1972) as well as Working Paper No.47, Preparation for Degree Courses. The BUTLER-BRIAULT proposals generated much controversy but the five-subject two-level Normal (N) and Further (F) examination had solid support. Paul Black edited a parallel Nuffield Foundation study, which was published in 1976. Unfortunately, not enough enthusiasm and commitment was forthcoming to implement reform into the post-16 curriculum and in July 1979 the N and F proposals were rejected by the Government.

111. Meeting on Sixth Form Education for Scientists in Caius College Cambridge, 14-16 September 1967 organised by SIR NEVILL MOTT and sponsored by Nature. The views expressed were published: Towrads a Broader Curriculum, Nature, Vol.215, 23 September 1967, 1319-1320, 1329-1334.

PARTICIPANTS

J.T. ALLANSON	Professor of Electronic and Electrical Engineering, University of Birmingham.
C.F. CARTER	Vice-Chancellor, University of Lancaster
R. CHRISTOPHER	Secretary of the Joint Matriculation Board.
JOHN DANCY	Headmaster, Marlborough College.
J. DIAMOND	Professor of Mechanical Engineering, University of Manchester.
L.R.B. ELTON	Professor of Physics, University of Surrey.
H.L. ELVIN	Director, Institute of Education, University of London
A.H. JENNINGS	Headmaster, Ecclesfield Grammar School, Sheffield.
K. HOSELITZ	Deputy Director, Mullard Research Laboratories, Redhill, Surrey.
K.W. KEOHANE	Professor of Physics, Chelsea College of Science and Technology, Co-ordinator of Nuffield Science Teaching Project.
J.A. LAUWERYS	Professor of Education, Institute of Education, University of London.

T. McMULLEN Director, Nuffield Resources for Learning Project.
MISS MARGARET MILES Headmistrees, Mayfield School, Putney.
E.W.J. MITCHELL Professor of Physics, University of Reading.
J.S. MORRISON President, University College, Cambridge.
SIR NEVILL MOTT Professor of Physics, University of Cambridge.
A.D.I. NICOL Secretary of the Council of the School of Physical Sciences, University of Cambridge.
CHRISTOPHER PRICE, MP
L. ROSENHEAD Professor of Applied Mathematics, University of Liverpool.
S.J. TESTER Lecturer in Classics, University of Bristol.
MRS. SHIRLEY WILLIAMS MP, Minister of State for Education and Science (for one session).

112. J.C. DANCY, Notes on Sir Nevill Mott's Meeting - Caius College, Cambridge on 14-16 September 1967. Spice Papers.

113. G. McGULLOCH, op. cit. 65, p.714

114. D. LAWTON, Education, Culture and the National Curriculum, Hodder and Stoughton (1989), p.75.

115. A.D.C. PETERSON, op. cit. 108, p.80.

116. G. GASTON to K. KEOHANE, 22 July 1968. Keohane Papers.

117. D. LAWTON, op.cit. 114, p.76.

118. P.J. BLACK and J.M. OGBORN to Professor MOTT, 12 July 1968. Mott Papers.

119. K.W. KEOHANE to P.J. BLACK and J.M. OGBORN, 17 July 1968. Keohane Papers.

120. N.F. MOTT to P.J. BLACK AND J.M. OGBORN, 17 July 1968. Mott Papers.

121. R. NYHOLM, School Science - education, preparation or indoctrination?, SSR, 49, 659 - 669.

122. T. BECHER and S. MACLURE. The politics of Curriculum Change. Hutchinson (1978), p.164.

123. P.J. BLACK and J. OGBORN, The Nuffield physicist in the university, Phys. Educ., 7, 1972, 66-70.

124. NFSTP, A-level Physics Newsletter, December 1968.

125. N.F. MOTT to V.J. LONG, 21 February 1967. File NAP 1.

126. B. CHAPMAN, Credit for Nuffield, Phys. Bull., 24, 1973, p.388.
In 1973 Black and Ogborn were jointly awarded the Bragg Medal and Prize by the Institute of Physics for their work on NAP. See: Phys. Bull., Vol.24, 1973, p.93.

127. NUFFIELD ADVANCED SCIENCE, op.cit.54, p.viii.

128. J. OGBORN, op.cit. 32.

129. J. OGBORN, The Role of Objectives, Studies in Science Education, 14, 1987, 143-144.

CHAPTER 4 - REFERENCES and NOTES

1. NUFFIELD ADVANCED SCIENCE, Physics teachers' handbook, Penguin Books Ltd(1971), p.46.

2. J.F.KERR, Science teaching and social change, SSR, Vol.XLVII, 1966, 301-309.

3. G.WHITTY and M.YOUNG (Eds), Explorations in the Politics of School Knowledge, Nafferton Books(1976), p.2.

4. Professor J.OGBORN, interview with K.D.FULLER. 15 February 1991.

5. NAB: P.J.KELLY, Some notes dealing with the School Trials (1966-68), 5 October 1965. Keohane Papers.

NAC: M.WARING, The Implementation of Curriculum Change in School Science in England and Wales, Eur.J.Sci.Educ., Vol.1, 1979, 257-275.

There is evidence that NOC deliberately used trials schools as secondary centres for dissemination, and the continuity of approach from NOC to NAC suggests an extension of this idea into the A-level developments. See: R.B.NICODEMUS, E.W.JENKINS AND R.B.INGLE, Adopting Nuffield O- and A-level Chemistry, Education in Chemistry, Vol.13, 1976, 46-49.

6. Professor J.OGBORN, op.cit. 4.

7. Professor P.BLACK, interview with K.D.FULLER, 28 October 1981.

8. J.M.OGBORN to K.KEOHANE, 25 January 1968. Keohane Papers.

9. Professor J.OGBORN, op.cit. 4.

10. W.F.ARCHENHOLD, communication with K.D.FULLER, 18 March 1991. File NAP 1.

W.F.(Fred) ARCHENHOLD graduated from Leeds University in 1956 and whilst working in the research laboratories at English Electric became interested in teaching technicians. He started teaching in 1958 and in 1962 he moved to Huddersfield New College as Head of Physics and subsequently Head of Science. During the NAP first trials in 1969 he joined the Centre for Studies in Science and Mathematics Education at the University of Leeds and in 1982 was appointed Director of the Centre. He later became Dean of the Faculty of Education at Leeds.

11. NFSTP, A-level Physics Newsletter, No.6, December 1968.

12. ibid.

13. W.F.ARCHENHOLD, op.cit. 10.

14. W.F.ARCHENHOLD, Teaching for understanding, Phys.Educ., Vol.11, 1976, p.449.

15. E.J.WENHAM to J.OGBORN, 14 February 1970. Wenham Papers.

16. A.S.WILTSHIRE, Nuffield advanced physics, Phys.Bull., Vol.20, 1970, p.422.

17. P.J.BLACK, Nuffield advanced physics, Phys.Bull., Vol.20, 1970, p.422.

18. Professor J.OGBORN, op.cit. 4.

19. ibid.

20. J.WILMUT to K.D.FULLER, 23 November 1981. File NAP 1.

21. S.PASCOE interview with K.D.FULLER, 26 April 1991.
Simon Pascoe taught Physics and Electronics at Highbury College of Technology, Portsmouth, from 1965 to 1974. He graduated from the University of Bristol in 1962. In 1974 he moved to The South Downs College of Further Education and helped introduce NAP, NAC and NAB into the College curriculum. He was Head of the Department of Science and Mathematics.

22. ibid.

23. ibid.

24. P.DRAKE, Experiences and Warnings, NFSTP Advanced Physics Newsletter, No.21, December 1971.

25. M.ALSOP, Experiences and Warnings, NFSTP Advanced Physics Newsletter, No.21, December 1971.

26. ibid.

27. J.M.HARDING, P.J.KELLY and R.B.NICODEMUS, The Study of Curriculum Change, Studies in Science Education, Vol.3, 1976, 1-30.

28. D.TAWNEY (Ed), Curriculum Evaluation Today: Trends and Implications, Schools Council Research Studies (1976), p.24.

29. P.KELLY, From innovation to adaptability: the changing perspective of curriculum development, in Curriculum change: The lessons of a decade. M.GALTON (Ed), Leicester University Press (1980). pp.68-71.

30. J.OGBORN, op.cit. 4.

31. K.COOPER, Curriculum diffusion: some concepts and their consequences, Research Intelligence, Vol.3, 1977, 6-7.

32. M.J.TEBBUTT, Teachers' views about the Nuffield advanced physics course, Phys.Educ., Vol.16, 1981, 228-233.

33. R.INGLE and A.JENNINGS, Science in Schools: Which Way Now?, Heinemann Educational Books (1981), p.51, lists four main sources on the degree of uptake of NAP course materials.

1.The study of examination entries:

M.J.TEBBUTT, The Growth and Eventual Impact of Curriculum Development Projects in Science and Mathematics, J.Curriculum Studies, Vol.10, 1978, 61-73.

M.J.TEBBUTT and M.A.ATHERTON, A 'Reaction Kinetics' Model for the Growth of Curriculum Projects, J.Curriculum Studies, Vol.11, 1979, 159-166.

THE INSTITUTE OF PHYSICS, Statistics relating to Education and Physics, 1986.

J.R.CRELLIN, R.J.J.ORTON and D.A.TAWNEY, Present-day school physics syllabuses, Rep.Prog.Phys., 42, 1979, 677-725.

2.The research of the Curriculum Diffusion Research Project:

J.M.HARDING, P.J.KELLY and R.B.NICODEMUS, The Study of Curriculum Change, Studies in Science Education, 3, 1976, 1-30.

M.WARING, The Implementation of Curriculum Change in School Science in England and Wales, Eur.J.Sci.Educ., 1, 1979, 257-275.

R.B.NICODEMUS, Discrepancies in Measuring Adoption of New Curriculum Projects, Educ.in Sci., 65, 1975, 26-28.

R.B.NICODEMUS, Why science teachers adopt new curriculum projects, Educational Research, Vol.19, 1977, 83-91.

3.Surveys conducted by HMI and other researchers:

N.BOOTH, HMI, The Impact of Science Teaching Projects on Secondary Education, Educ.in Sci., 63, 1975, 27-30.

HMI, Aspects of Secondary Education in England summarised in Education in Science, Educ.in Sci., 86, 1979, 10-22.

H.BRADLEY, A Survey of Science Teaching in Secondary Schools, The University of Nottingham School of Education (1976).

G.TALL, British Science Curriculum Projects - How have they taken root in schools?, Eur.J.Sci.Educ., 3, 1981, 17-38.

D.J.WHITEHEAD, The Dissemination of Educational Innovations in Britain, Hodder and Stoughton(1980), pp.52-57.

4.Schools Council enquiries:

SCHOOLS COUNCIL, NFSTP: Survey of adoption by schools and support by local education authorities, Educ.in Sci., Vol.32, 1969, 20-23.

S.D.STEADMAN, C.PARSONS, B.G.SALTER, Impact and Take-up Project, A Second Interim Report to the Schools Council, Schools Council Publications (1980).

34. Taken from:
G.TALL, British Science Curriculum Projects - How Have They Taken Root in Schools?, Eur.J.Sci.Educ., Vol.3, 1981, 17-38.

35. Taken from:
HMI, Aspects of Secondary Education in England, HMSO (1979).

36. I.F.GOODSON and R.WALKER, Biography, Identity and Schooling: Episodes in Educational Research, The Falmer Press (1991), p.8.

37. R.B.NICODEMUS, Discrepancies in Measuring Adoption of New Curriculum Projects, Educ.in Sci., Vol.65, 1975, 26-28.

38. R.INGLE and A.JENNINGS, op.cit. 33, p.52.

39. M.J.TEBBUTT, The Growth and Eventual Impact of Curriculum Development Projects in Science and Mathematics, J.Curriculum Studies, Vol.10, 1978, 61-73.

40. J.R.CRELLIN, R.J.J.ORTON and D.A.TAWNEY, Present-day School physics syllabuses, Rep.Prog.Phys., Vol.42, 1979, 677-725.

41. M.J.TEBBUTT, op.cit. 39.

42. Professor J.OGBORN, op.cit. 4.

43. M.J.TEBBUTT and M.A.ATHERTON, A 'Reaction Kinetics' Model for the Growth of Curriculum Projects, J.Curriculum Studies, Vol.11, 1979, 159-166.

44. J.OGBORN, op.cit. 4.

45. W.F.ARCHENHOLD, op.cit. 10.

Conscious of the fact that the Individual Investigations was the one unique aspect of the NAP examination profile, ARCHENHOLD became an Examiner for this section. He has also had a long association with the JMB Physics examinations and helped develop Short Practical tasks which eventually found their way into the NAP examination profile. Archenhold has also published a useful review of A-level examinations: W.F.ARCHENHOLD, GCE and SCE examinations in physics, Recent changes, statistics and proposed developments, Phys.Educ., Vol.7, 1972, 88-96.

46. PHYSICS EDUCATION, Volume 10, 1975, devoted most of this issue to books useful for A-level Physics courses. In the early 1970s text books had responded to the NAP course and to changes made in new A-level syllabuses:

T.DUNCAN, Advanced Physics: Materials and Mechanics, John Murray (1973).
T.DUNCAN, Advanced Physics: Fields, Waves and Atoms, John Murray(1975).
W.BOLTON, Patterns in Physics, McGraw-Hill (1974).
E.J.WENHAM, G.W.DORLING, J.A.N.SNELL and B.TAYLOR, Physics - Concepts and Models, Addison-Wesley(1972).
M.NELKON, Principles of Physics, Chatto and Windus (1973).
P.M.WHELAN and M.J.HODGSON, Essential Pre-University Physics, John Murray (1971).

47. HMI, op.cit. 35, p.205.

48. G.TALL, op.cit. 34.

49. W.F.ARCHENHOLD, op.cit. 10.

50. M.KINGDON, The Reform of Advanced Level, Hodder and Stoughton (1991), p.76.

51. J.R.CRELLIN et al, op.cit. 40.

52. M.KINGDON, op.cit. 50, p.76.

53. A.STEPHENSON to C.C.BUTLER, 4 March 1975. Nuffield Foundation.

54. J.R.CRELLIN et al, op.cit. 40.
The definitions of the abilities are derived from B.S.BLOOM (Ed.), Taxonomy of Educational Objectives: Handbook I, Longmans (1956), and are eventually used in the syllabus construction of the London Board's A-level Physics in 1980-81.

55. H.B.GILBODY to K.KEOHANE, 9 October 1970. Keohane Papers.

56. M.J.TEBBUTT, Preliminary Report on Survey of Nuffield A-level Physics Teachers, August 1979. File NAP 1.

57. J.O.HEAD, Nuffield A-levels and undergraduate performance, SSR, Vol.56, 1975, 601-604.

58. M.RIDLEY, interview with K.D.FULLER, 1 May 1991.
Michael RIDLEY graduated from Keele University in 1968 and taught physics in a number of comprehensive schools in the Hemel Hempstead area before becoming Head of Physics at the John F.Kennedy School in 1979, where he introduced NAP. In 1986 he was appointed Head of Physics and Microtechnology at Strodes College (an open access sixth-form College in Egham, Surrey), where he taught the JMB A-level Physics course and then the new Institute of Physics Advancing Physics AS and A2 courses.

59. M.B.RIDLEY, An investigation into the attitudes at universities towards Nuffield and traditional A-level physics, SSR, Vol.63, 1982, 556-557.

60. M.B.RIDLEY, op.cit. 58.

61. C.D.GOULD, The impact of Nuffield O-level Biology - an agent of change in biology teaching?, J.of Bio.Educ., Vol.17, 1983, 201-204.

62. G.TALL, op.cit. 34.

63. Photocopies of the 1984 NAP examination entry for each school were supplied by Mrs.B.Fraser, Assistant Secretary, The Oxford and Cambridge Schools Examination Board; 1984 was the last year in which the original NAP course was examined before the publication of the Revised NAP in 1985 (The first RNAP examination was 1987). Data was not available from two sources with a history of small NAP entries: the Southern Universities' Joint Board (which closed in 1990) entered about 20 NAP candidates each year, and the Northern Ireland Schools Examinations and Assessment Council were entering about 15 NAP candidates, a significant fall from the 100 who entered in 1974. The total NAP entry, by this method, is 9,438, compared with the O and C Board's official figure of 9,279. Some students who enter for the NAP examination do not sit the final exam and for some Boards it was difficult to distinguish between A-level and S-level entries on their own computer print-outs. The choice of Independent versus State schools was based on a listing of Independent Schools given in: K.BOEHM and J.LEES-SPALDING (Eds): The Equitable Schools Book, published by the Equitable Life Insurance Company. It is worth noting Tebbutt's finding (see reference 55) that schools change name and status with, for example, Direct Grant schools becoming Comprehensive or Sixth-form Colleges. Therefore, data built up from a 'school base' has some degree of uncertainty. Finally, it must be pointed out that some State schools are, of course, selective and that Sela's study supports the data supplied here.

D.SELA, Teachers' and Students' Reactions to the Revised Nuffield A-level Physics Course, King's College London (1988), found the following proportions of RNAP schools:

Comprehensive 45%, Selective(Independent and Grammar) 35%, Colleges 18%, Other 2%.

64. NFSTP, Draft of progress report, October 1964. Nuffield Foundation.

65. Nuffield O-level Physics estimate in: G.VAN PRAAGH, What it costs to go Nuffield, The Times Educational Supplement, 5 May 1967, pp.1517-1522.

Nuffield A-level Physics estimate in: NUFFIELD ADVANCED PHYSICS PROJECT, Newsletter No.21, December 1971.

66. K.W.KEOHANE, The Future of the £1,333,000 Revolution, The Times Educational Supplement, 5 May 1967, p.1518.

67. D.M.CHILLINGWORTH, Is Nuffield Physics worth the money?, Education, 3 March 1967, 426-432.

68. J.M.HARDING, Communication and support for change in school science education, unpublished Ph.D. thesis, Chelsea College, University of London (1975).

69. HAMPSHIRE EDUCATION COMMITTEE, Minute 297 of a meeting held on 5 July 1966 at the Castle, Winchester. Hampshire LEA Archive.

70. H.B.LEE, interview with K.D.FULLER, 9 October 1981.

71. S.PASCOE, op.cit. 21.

72. J.L.LEWIS, From Daniell cell to the apparatus kit, Phys.Educ., Vol. 4, 1969, 257 263.

73. R.PARRY, interview with K.D.FULLER, 12 March 1982.

74. J.M.HARDING et al, op.cit. 27.

75. K.THOMAS, School physics for the 1980s, Phys.Bull., Vol. 28, 1977, 100-101.

76. M.J.TEBBUTT, op.cit. 32.

77. E.C.E.WILLIS, School physics, Phys.Bull., Vol.28, 1977, p.200.

78. D.WILLIAMS, School physics, Phys.Bull., Vol.28, 1977, 199-200.

79. T.M.AULD, interview with K.D.FULLER, 7 August 1981.

80. J.F.KERR, Practical work in School Science, Leicester University Press (1963), p.40.

81. J.J.THOMPSON (Ed.), Practical work in Sixth Form Science, Science Centre, University of Oxford (1975), p.20.

82. J.G.JONES and J.L.LEWIS, The Role of the Laboratory in Physics Education, John Goodman and Sons (1978).

E.W.JENKINS and R.C.WHITFIELD (Eds.),Readings in Science Education. A source book. McGraw-Hill (1974).

ADVANCED PHYSICS PROJECT FOR INDEPENDENT LEARNING(APPIL), Student's Handbook, John Murray (1978).

ASE, Education through Science, SSR, Vol.63, 1981, 5-52.

B.E.WOOLNOUGH, Practical work in sixth-form physics, Phys.Educ., Vol 11, 1976, 392-397.

83. J.BADDELEY, Teaching and philosophy of science through Nuffield schemes, SSR, Vol.62, 1980,154-159.

P.STEVENS, On the Nuffield Philosophy of Science, J.of Phil.of Educ., Vol.12, 1978, 99-110.

84. J.G.JONES and J.L.LEWIS, op.cit. 82, p.60.

85. J.J.THOMPSON, op.cit. 81, p.71.

86. W.D.HALLS (Ed.), European Curriculum Studies: No.6 Physics, Council of Europe (1972).

See also: I.SLADE, Education in West Germany with practical reference to the teaching of physics, unpublished M.Sc. dissertation. University of Reading (1976).

87. M.DENNY and F.CHENNELL, Science practicals: what do pupils think?, Eur.J.of Sc.Educ., Vol.8, 1986, 325-336.

88. J.MADDOX, The Future of the Nuffield Projects, Educ.in Sc., June 1966, 24-29.

D.TAWNEY, Physics during the First Three Years of Secondary School in England and Wales, in Physics Teaching in Schools , G.DELACOTE (Ed.), Taylor and Francis Ltd.(1978).

89. G.COOK, Teaching styles in the Nuffield A-level Physics course, SSR, Vol.60, 1978, 348-350.

90. D.H.MONK, Resource Allocation in Classrooms: an economic analysis, J.Curriculum Studies, Vol.14, 167-181.

91. B.E.WOOLNOUGH, Physics Teaching in Schools 1960-85: Of People, Policy and Power, The Falmer Press (1988), p.220.

92. H.NIELSON and P.THOMSEN, Crisis in physics education, in Science Education and the History of Physics, P.V.THOMSEN (Ed.), proceedings of the multi-national teacher/teacher training conference, Deutches Museum, Munich, 3-9 May 1986, pp.9-23.

93. M.WARING, op.cit. 5.

94. G.TALL, The processes of curriculum development and evaluation, J.Curriculum Studies, 21, 1989, 271-276.

Tall's essay reviewed the historical account of the processes of the Australian Science Education Project found in The processes of Curriculum Development and Evaluation: A Retrospective Account of the Processes of the Australian Science

Education Project, D.COHEN and B.J.FRASER, The Curriculum Development Centre, Australia (1987).

95. J.M.ATKIN, The Government of the Classroom, University of London Institute of Education (1980).

G.BLENKIN, The influence of initial styles of curriculum development, in Curriculum Context, A.V.KELLY (Ed.), Harper and Row Limited (1980), pp.44-60.

96. M.SKILBECK, School-based curriculum development, in Planning in the Curriculum, V.LEE and D.ZELDIN (Eds.), Hodder and Stoughton (1982), pp.28-31.

97. SECONDARY SCIENCE CURRICULUM REVIEW (SSCR)

The SSCR grew out of the then Labour Government's 'great debate' to improve education standards, following Callaghan's Ruskin College speech on 18 October 1976. In partnership with the ASE and the Schools Council, the DES helped fund the SSCR from its tentative origins in 1979 to its completion in 1989 (about £1million was spent). In 1979 John SPICE chaired a joint working party to establish curriculum guidelines, which involved a combination of the centre-periphery model and local curriculum development.

Dr.Dick West, then 45, was appointed as Director of the SSCR from 1 September 1981 and he held the office until September 1985. His successor was Dr.Jeff KIRKHAM, who directed the SSCR until its completion in August 1989. As yet, no detailed history of the SSCR has been written. The SSCR was the first major science curriculum development after the NFSTP and, as such, provides a comparison to the NOP and NAP initiatives.

A selection of articles dealing with the SSCR:

R.W.WEST, Context and content, The Times Educational Supplement, 18 September 1981, 33-34.

R.W.WEST, The Secondary Science Curriculum Review, Education in Science, No.99, September 1982, 29-31.

R.W.WEST, Purpose and values in science education, SSR, Vol.64, March 1983, 407-417.

SSCR, Science Education 11-16: proposals for action and consultation, April 1983.

R.W.WEST, SSCR - a progress report, Phys.Educ., Vol.19, 1984, 182-186.

SSCR, An Education Digest, Education, 7 June 1985.

SSCR Better Science Pack:

Curriculum Guides: Guide 1. Key Proposals, compiled by Mick Michell; Guide 2. Choosing Content, compiled by Mike Watts and M.Michell; Guide 3. Making it Relevant to Young People, compiled by Denis Stewart; Guide 4. Approaches to Teaching and Learning, compiled by E.Ellington; Guide 5. How to Plan and Manage the Curriculum, compiled by John Heaney; Guide 6. For Both Girls and Boys, compiled by Christine Ditchfield; Guide 7. Working for a Multicultural Society, compiled by C.Ditchfield;

Guide 8. For Young People with Special Educational Needs, compiled by C.Ditchfield; Guide 9. Health and Science Education, compiled by Di Bentley; Guide 10. Building Primary-Secondary Links, compiled by Brenda Barber; Guide 11. Assessing Progress, compiled by Cathy Wilson; Guide 12. Learning How to Teach It, compiled by Joseph Hornsby.

Other publications: Making it Happen, edited by Maureen O'Connor, and A Directory of Resources, Heinemann Educational Books(1987).

98. NUFFIELD-CHELSEA CURRICULUM TRUST, Minutes of the 21st meeting of the Governing Body, held at Chelsea College on 15 November 1984. NCCT Archive.

99. L.STENHOUSE (Ed.), Curriculum Research and Development in Action, Heinemann Educational Books (1980), p.262.

100. K.W.KEOHANE, New Science and old cultures, Phys.Educ., Vol.11, 1976, 16-18.

101. NUFFIELD-CHELSEA CURRICULUM TRUST, Report by the Publications Manager to the Governors' Meeting held on 7 November 1986. NCCT Archive.

The first General Certificate of Secondary Education (GCSE) examinations were held in the summer of 1988, taking over the role formerly played by a combination of the O-level examination of the GCE Examining Boards and the Certificate of Secondary Education of the original CSE Examinations Boards. Criterion-referencing formed the basis of the assessment.

For details see: D.L.NUTTALL, Doomsday of a New Dawn? The Prospects for a Common System of Examining at 16+, in Curriculum and Assessment: some policy issues , P.RAGGATT and G.WEINER (Eds.), The Open University and Pergamon Press (1985), pp.91-105.

102. G.BUSH, The Key to Stage Three? Geoff Bush explains how his school has coped. The Times Educational Supplement, 29 December 1989, p.26.

The 1988 Education Reform Act legalized the issue of a centrally determined national core curriculum for all 5-16 year olds in state schools in England and Wales. As a result there came into being a very different model for centralized, 'national' curriculum renewal. It involves Government appointed subject Working Parties whose interim reports are subject to wide public and institutional consultation, often at short notice. The Working Parties' final reports receive further wide consultation linked to a Consultative Report then produced by the National Curriculum Council (NCC) and now to the Schools Curriculum and Assessment Authority (SCAA). The Government then issues draft Statutory Orders, which receive limited consultations and, finally, Statutory Orders generate the legal curriculum. The outcome can be massaged by the Secretaries of State, using advice originally from the NCC and SEAC and now from SCAA. Useful articles on the background and consequences of the Education Reform Act are:

C.CHITTY, Central control of the school curriculum, 1944-87, History of Education, Vol.17, 1988, 321-334.

A.HARTNETT and M.NAISH, The sleep of reason breeds monsters: the birth of a statutory curriculum in England and Wales, J.Curriculum Studies, Vol22, 1990, 1 16.

I.F.GOODSON, 'Nations at risk' and 'national curriculum': ideology and identity, J.of Education Policy, Vol.5, 1990, 219-232.

103. W.J.HUGHES, Degree of teacher guidance as a measure of the discrepancy between intention and reality in science curriculum materials, Studies in Educational Evaluation, Vol.4, 1978, 91-98.

104. B.E.WOOLNOUGH, Changes in Physics Teaching in England since 1960: The People, Policies and Power in Curriculum Administration, in Case Studies in Curriculum Administration History, H.HAFT and S.HOPMANN (Eds.), The Falmer Press (1990), p.136.

105. B.E.WOOLNOUGH, op.cit. 91, p.78.

106. D.D.MALVERN, communication with K.D.FULLER, 12 July 1991.

The influence of the PSSC and NOP is apparent in P.E.HEAFFORD, The Teaching of Science, in Techniques of Teaching, Volume 2, Secondary Education , A.D.C.PETERSON (Ed.), Pergamon Press (1966), pp.81-105.

107. H.NIELSON and P.THOMSEN, op.cit. 92, p.11.

108. A.W.PELL, Subject swings at A level: attitudes to physics, SSR, Vol.58, 1977, 763 770.

109. J.OGBORN, op.cit. 4.

In 1989, 5332 boys and 2375 girls sat the RNAP examination. It is only very recently that gender statistics have been made available. Sela's study (see reference 63) indicates that most of these girls came from comprehensive and selective schools.

110. G.R.MEYER, Reactions of Pupils to Nuffield Science Teaching Project Trial Materials in England at the Ordinary level of the General Certificate of Education, J.of Res.in Sci.Teaching, Vol.7, 1970, 283-302.

111. DES, Advancing A levels (The Higginson Report), Report of a Committee appointed by the Secretary of State for Education and Science and the Secretary of State for Wales, HMSO (1988).

Dr.Gordon HIGGINSON, Vice-Chancellor of the University of Southampton, was given a little over one year to present the report. His committee was asked to exclude subject specific questions, so his recommendations were broadly based: five rather than three A-levels, leaner and tougher syllabuses, concentrate on high-level skills, compulsory core for subjects, few A-level syllabuses, in-course assessment for 20% of final mark, flexible transfer between A-levels and BTEC. The proposals were dismissed by the Government just a few minutes before the major press conference which had been arranged to publicise the recommendations. However, the Higginson proposals received

wide public support in the literature. In particular, the physics staff at Peter Symonds' College wrote a long letter pointing out that NAP met most of the Higginson criteria. See R.PARRY, D.HENDERSON, L.WHITE, P.NORTHCOTT, S.TAYLOR: Lean physics, letter in The Times Educational Supplement, 24 June 1988, p.21.

112. W.F.ARCHENHOLD, op.cit. 10.

CHAPTER 5 - REFERENCES AND NOTES

A note on methodology

The data for the origins of the NCCT are taken from published papers and personal correspondence kept in the NCCT Archive. This evidence was cross-referenced with data uncovered at the Nuffield Foundation in files that accompany the Minutes of the Trustees' meetings. Some further primary evidence was also to be found in Keohane's correspondence. Furthermore, the last part of Black's interview in 1988 covered the processes of the NCCT in initiating curriculum revision and renewal, and his recollections were set alongside the evidence obtained in print.

Data about the revision of NAP were, of course, included in all the sources listed above. However, supporting evidence emerged from an extended interview with Harris and, further, from access to Harris' personal papers and correspondence. Also a number of published and unpublished evaluation papers and research provided a framework upon which to triangulate all the diverse sources of evidence about the revision processes for the RNAP course.

1. Minutes of the 159th Meeting of the Trustees of the Nuffield Foundation, held on Friday 17 September 1967 at Nuffield Lodge.

2. ibid.

3. K.KEOHANE, Chelsea College of Science and Technology Centre for Science Education, 20 December 1966, EDU/52. Nuffield Foundation.

4. R.BECHER, Note of a discussion with Dr.Gavin and Professor Keohane on the plans of the Chelsea Science Teaching Centre on Friday 28 October 1966, EDU/52. Nuffield Foundation.

5. Sir Eric ASHBY. In 1967 Ashby was a member of the University Grants Committee (1959-67) and Chairman of the Education Committee. He was also Vice-Chancellor of the University of Cambridge(1967-69). As with Mott, Ashby spent a period of time lecturing at Bristol University - Reader in Biology 1935-37.

6. M.GAVIN to N.F.MOTT 19 April 1967. Mott Papers.

7. NUFFIELD FOUNDATION TRUSTEES, op.cit. 1.

The Trustees accepted the responsibility for the continuation of the O-level science projects during 1965 and allocated £12,000 for a small team (one person from NOP, NOB, NOC) to answer the steady flow of requests until August 1966. Dr.Gordon

Van Praagh from the NOC project assumed total responsibility for this continuation and the Trustees allowed a further £38,000 for future requirements in this area.

8. The Centre's name was enlarged to The Centre for Science and Mathematics Education and the following academic staff were appointed in 1968, in addition to Keohane and Mathews:

Mr.Peter J.Kelly, M.A.,B.Sc., Senior Lecturer in Biological Education, then Organizer of the Nuffield A-level Biology Project.

Mrs.Hilda Misselbrook, B.Sc., Senior Research Fellow in Curriculum Studies, then Organizer of the Nuffield Secondary Science Project.

Mr.W.H.Lloyd, B.Sc., Lecturer in Chemical Education, a graduate in chemistry with wide experience of teacher training and a particular interest in chemistry method and the design of laboratories.

Mr.A.J.Malpas, M.A., B.Sc., Lecturer in Chemical Education, a chemistry graduate with post-graduate qualifications in psychology, with a special interest in concept formation.

Dr.Erica Glynn, Ph.D., Chemist with wide teaching experience at degree level, Research Fellow in Programmed Learning.

Mr. H.Faulkner, B.Sc., Senior Lecturer in Education, physics graduate with special knowledge of Educational Administration and in-service training schemes.

Mr.R.W.Fairbrother, B.Sc., Lecturer in Physics Education, graduate physicist and a member of the Nuffield A-level Physics team.

Mr.R.N.Ryder, M.A., Lecturer in Education, with experience in the audio-visual and television fields.

Dr.J.Harris, Ph.D., Research Fellow in Curriculum Studies: a physicist who worked on the Harvard Physics Project and with special interest in apparatus development.

Dr.L.C.Jesty, D.Sc., Senior Research Fellow in educational technology, formerly of the Westinghouse Corporation of America and with special interest in computer aided instruction and the visual presentation of data.

Mr.J.A.Barker, B.Sc., Lecturer in Biological Education,who was both an area leader and a consultant to Nuffield Biology Projects.

Mr.H.Silver, M.A.,M.Ed., a non-scientist who had published widely and with an interest in the growth of the technological society and the impact of science on the community.

Mr.B.Lodwick, B.Sc.,M.A., Lecturer in Educational Psychology.

Mr.B.S.Mowl, B.Sc., Schoolteacher Fellow in Biology.

Mr.R.Lewis, B.Sc., Research Fellow in Mathematics for Science.

Sir Nevill Mott, F.R.S., also joined the Centre as adviser to the investigations into mathematics for science.

Over half the appointments were involved in the NFSTP.

9. B.YOUNG to M.GAVIN 24 December 1968, EDU/52. Nuffield Foundation.

10. ibid.

11. B.YOUNG, Note of a telephone conversation with Professor KEOHANE 30 January 1969, EDU/52. Nuffield Foundation. The Continuation Committee was eventually enlarged to include:

Dr.M.R.Gavin (Chairman)
Dr.C.C.Butler, FRS (Director, Nuffield Foundation)
Dr.T.Burdett (Schools Council)
Professor J.H.Burnett (University of Oxford)
Mr.P.Coles (Buckinghamshire Education Authority)
Mr.A.Ellis (Cheadle Hulme School)
Sister Maureen Hurst (La Retraite School)
Professor J.Lewis, FRS (University of Cambridge)
Professor D.J.Millen (University College. London)
Professor Sir Nevill Mott, FRS (Chairman, Consultative Committee)
Dr.P.Sykes (University of Cambridge)
Mr.R.A.Becher (Nuffield Foundation)
Mr.W.Anderson (Nuffield Publications)
Mr.R.Marshall (Nuffield Foundation)
Mr.D.Tosey (Finance Officer, Chelsea)
Professor K.W.Keohane (Coordinator, Nuffield Projects)

12. Professor C.C.BUTLER, FRS, Director of the Nuffield Foundation from 1 January 1971 (part-time during 1970) until his resignation in March 1975 to become Vice-Chancellor of the Loughborough University of Technology. At the time of his appointment as Director, Butler was Head of the Physics Department at Imperial College, London. He was a member of the UGC and Chairman both of the Schools Council-SCUE Joint Working Group on the sixth-form curriculum and examinations, and of the Royal Society's Standing Conference on Education.

13. NUFFIELD-CHELSEA CONTINUATION COMMITTEE Minutes of a meeting held at Chelsea College on 11 February 1972 at 2.30pm. NCCT Archive.It was reported that allocation for 1972-73 would total £67,575, a tiny budget when compared with the original injection of capital into the NFSTP.

Item 6, the Nuffield 16+ Science Project (later, the Nuffield Working with Science Project) devised science-based materials for the post-16 pupils remaining in full time education but not following A-level courses. For details of the materials and the project development see K.WILD and J.K.GILBERT, A progress report of the Nuffield Working with Science Project, SSR, Vol. 58, 1977, 560-570.

14. Minutes of the 223rd meeting of the Trustees of the Nuffield Foundation held on Thursday 6 March 1975 at Nuffield Lodge.

15. THE NUFFIELD FOUNDATION, Projects and Royalties Paper No. E.68.12/3, EDU/52. Nuffield Foundation.

16. ibid.

17. C.BUTLER to D.INGRAM, 14 March 1975, EDU/52. Nuffield Foundation. Dr. David Ingram replaced Dr.Malcolm Gavin as Principal of Chelsea College.

18. J.MADDOX, Nuffield Science and Language Continuation Programmes. Paper E.75 11/2, prepared for the 228th Meeting of the Trustees held on 28 November 1975, EDU/52, Nuffield Foundation.

19. The bulk of the income to the Nuffield Foundation derived from commission agreements with the publishers Longman. A steadily deteriorating revenue from sales occurred in the period 1971-76: £434,000 in 1971 to £280,000 in 1976. To make matters worse Michael Spincer, at Longman Group Limited, estimated that delays and problems in publishing the Revised NOP books had cost the Foundation about £250,000 in the years 1975-77.

The O-level revisions were carried out during the negotiations to form the NCCT so that decision making was split between Keohane at Chelsea and Becher at the Foundation, causing delays and confusion. Furthermore, at an early stage in the NOP revision Rogers' wife, whom he had met and married whilst a housemaster and physics teacher at Bedales School, in 1930, died suddenly. There was more than a year's delay as a result.

20. J.MADDOX, op.cit. 18.

21. W.SLADE to J.MADDOX, 23 September 1976, EDU/52. Nuffield Foundation.

22. NUFFIELD FOUNDATION, Minutes of a meeting between the Nuffield Foundation and Chelsea College held on Tuesday 5 October 1976 at Nuffield Lodge. File EDU/52. Nuffield Foundation. When the Nuffield-Chelsea Curriculum Trust was legally incorporated on 5 September 1979, the Nuffield Foundation nominated J.Maddox, W.D.Scott and Professor R.A.Becher as their Governors. The Council of Chelsea College elected A.J.Hill, W.C.Slade and Dr.D.J.Ingram as their Governors. Professor K.W.Keohane was appointed as Chairman. In addition, Professor P.J.Black accepted the role as Educational Consultant, with R.C.Marshall as General Manager and W.A.Anderson as Chief Editor.

23. P.STURROCK, Report on a proposal to establish a joint publishing trust by the Nuffield Foundation and Chelsea College, January 1978. A paper prepared for the 244th meeting of the Trustees held on Friday 24 February 1978 at Nuffield Lodge, EDU/52. Nuffield Foundation.

24. Minutes of the 249th Meeting of the Trustees of the Nuffield Foundation, held on Friday 22 December 1978 at Nuffield Lodge.

25. Minutes of the 255th Meeting of the Trustees of the Nuffield Foundation, held on Friday 19 October 1979 at Nuffield Lodge.

Even at this stage the Trustees preferred the name Chelsea-Nuffield Curriculum Trust and desired the opportunity to consider, in the future, the indefinite use of the description "Nuffield" on books arising from new projects.

The NCCT published accounts at 31 May 1980 showing total net current assets at £456,934.

26. D.INGRAM to J.MADDOX, 10 February 1976, EDU/52. Nuffield Foundation.

27. Professor P.BLACK interview with K.D.FULLER, 4 November 1988.

In 1974 Paul Black was appointed to a single tenure chair as Professor of Physics (Science Education) in the Physics Department of the University of Birmingham. This Chair was for his contribution to teaching both inside and outside the University, where his Readership had been for research excellence.

28. R.MARSHALL, Minutes of Science Teaching Publications Budget Meeting held on Friday 10 December 1976 at Nuffield Lodge, EDU/52. Nuffield Foundation.

29. Minutes of the 241st Meeting of the Trustees of the Nuffield Foundation, held on Friday 14 October 1977 at Nuffield Lodge.

In 1976 the Continuation Board had identified two urgent curriculum developments: the revision of A-level science was expected to exceed £100,000 and a Home Economics project in the order of £60,000 during the period 1978-80.

30. M.SPINCER to J.MADDOX, 21 September 1977, EDU/56. Nuffield Foundation.

31. ibid.

32. Meetings with M.Spincer, J.Maddox, K.Keohane, W.Anderson to discuss Nuffield A level Science:

PHYSICAL SCIENCE 30 June 1977 at Nuffield Lodge: J.Spice, K.Greenwood, S.Hockey, D.Hughes, J.Mills, C.Nickless, J.Swain.

PHYSICS 19 July 1977 at Crove House: Miss B.Carter, M.Detheridge.

CHEMISTRY 19 July 1977 at Crove House: T.Dempsey, M.Hudson, M.Vokins.

BIOLOGY 19 July 1977 at Crove House: C.Wood-Robinson, S.Newton, J.Barker, M.Tribe.

33. M.SPINCER, op.cit. 30.

34. ibid.

35. P.J.BLACK(Ed), Sixth-form Science and the N and F proposals, a study by the NFSTP, The Nuffield Foundation (1977).

List of Contributors to the Studies:

Biology	
John Barker	Chelsea College
W.H.Dowdeswell	University of Bath
Christopher Gayford	University of Reading
Richard Gliddon	Clifton College
Peter Kelly	Chelsea College
Robert Lister	Institute of Education, London.
Grace Monger	Holt School, Wokingham
Margaret Sands	University of Nottingham
Colin Stoneman	University of York
John Wray	Centre for Life Studies, ILEA
Sandra Wilson	Ricards Lodge High School, Merton

Chemistry	
John Biggins	Filton High School, Bristol
Ernest Coulson	formerly Chelsea College
Bernard Dawson	King's College, London
Brian Hitchin	W.R.Ruson College, Preston
Michael McNevin	Malvern College
John Mathews	University of Lancaster
Peter Rendle	Clifton College
Michael Vokins	University of Bristol

Physics	
Paul Black	Chelsea College
John Harris	Chelsea College
Jon Ogborn	Chelsea College
A.W.Trotter	formerly of North London Science Teachers' Centre

Also see:
P.J.BLACK Revolution in Sixth Form Studies, Phys.Bull., 29, 1978, 223-225.

36. Professor P.BLACK, op.cit. 27.

During 1968 SPICE and KEOHANE exchanged views on Spice's possible appointment to Chelsea College. Keohane was pessimistic, so that Spice, nearly 50, decided to remain at Winchester. In 1972 he became Staff Inspector of Science at the ILEA. Throughout the 1970s, NAPS increasingly developed a poor image in schools and university departments, which, of course, inhibited adoption. See:

J.R.L.SWAIN, Aspects of the non-adoption of the Nuffield physical science course, SSR, 58, 1976, 351-355.

J.R.L.SWAIN, Evaluation studies on the Nuffield Physical Science Course, 22 June 1977. Spice Papers.

The number of NAPS centres remained relatively constant - 75 in 1971, and 54 in 1977, - but the number of candidates dropped sharply, from 824 in 1971 to 447 in 1977. The inescapable conclusion was of significantly less demand for NAPS than there was ten years earlier when the course started trials. Spice places some of the inculpation for the decline on poor after care in the fact that he was not 'on call' at Chelsea College. A minor revision to NAPS was coordinated by Colin NICKLESS during 1979-81, but this did not halt the decline nor reduce the large stocks of unsold NAPS books. The final 'nail in the coffin' was the agreement to include common subject cores in A-level Chemistry and Physics.

37. NUFFIELD-CHELSEA CURRICULUM TRUST. Minutes of the Second Meeting of the Board of the Trust (in process of formation) on 18 June 1979 at Lillie Road. NCCT Archive.

	INITIAL ALLOCATION(1981)	SPENT(1985)
Revised NAC	£40,000	£62,000
Revised NAP	£49,000	£78,000
Revised NAB	£58,000	£90,000

In 1981 the expected income from sales in the first five years was £290,000. This figure was well and truly exceeded: Chemistry sales £481,000(1984-87); Physics sales £428,000 (1985-87); Biology sales £141,000 (1986-87).

38. M.FRAZER, Revised Nuffield A-level Chemistry, Educ.in Chem., 21, 1984, p.176.

39. P.BLACK, Revision of A-level courses, 17 October 1979. NCCT Archive.

40. NUFFIELD-CHELSEA CURRICULUM TRUST. Draft of a Report to the NCCT (about a revised version of Nuffield Advanced Chemistry) 26 February 1980. NCCT Archive.

41. REVISED NUFFIELD A-LEVEL CHEMISTRY, PHYSICAL CHEMISTRY: Professor M.Frazer (Chairman), Professor P.Black, Dr.T.Burrows, J.Holman, D.Mansfield, Professor D.Millen, J.Ogborn. A summary of this group's work is found in: J.HOLMAN, A new approach to chemical thermodynamics, Educ.in Chem., 21, 1984, 178-180.

42. NUFFIELD ADVANCED PHYSICS, Unit 9: Change and chance, Penguin Books Ltd.(1972).

International interest is seen in the following articles:

J.OGBORN, The second law of thermodynamics: a teaching problem and an opportunity, SSR, 57, 1976, 654-672. This paper was first presented in Hungary in 1975.

P.J.BLACK, P.DAVIES and J.M.OGBORN, A quantum shuffling game for teaching statistical mechanics, Am.J.of Phys., 39, 1971, 1154-1159.

T.ALLEN, Computer simulations: paramagnetism and adiabatic demagnetism, Phys.Educ., 24, 1989, 104-108. This article is based on a paper by A.Briquet, D.Gaveron and C.Ruhla from the University Claude-Bernard, Lyon, France, which in turn arose from a 'Change and Chance' lecture at the Congres de Montpellier in September 1976.

43. J.J.GUY and T.LISTER, Revised Nuffield A-level Chemistry: Critique, Educ.in Chem., 21, 1984, 183-184.

44. N.LUMB, Problems and rewards in teaching Nuffield A-level, Educ.in Chem., 9, 1972, 174-175.

45. C.MASON, Chemical milestone revisited, The Times Educational Supplement, 30 March 1980.
Organic chemistry group: M.Vokins (Chairman), J.Eggleton, G.James, Professor D.Waddington.

46. Inorganic chemistry group: A.Furse (Chairman), K.Badman, M.Cane, C.Nicholls, D.Russell.

47. E.H.COULSON, D.J.DEFOE and A.J.FURSE, Some individual approaches to the Nuffield Advanced Chemistry Course Part I, SSR, 59, 1977, 223-233.
J.A.HUNT and G.P.RENDLE, Some individual approaches to the Nuffield Advanced Chemistry Course Part II, SSR, 59, 1978, 454-463.
C.NICHOLLS and P.F.HIGGINS, Some individual approaches to the Nuffield Advanced Chemistry Course Part III, SSR, 59, 1978, 29-45.

48. J.J.GUY and T.LISTER, op.cit. 43, p.183.

49. A.HUNT, Revised Nuffield A-level Chemistry: The Special Studies, Educ.in Chem., 21, 1984, 181-182.
The Special Studies are not the practical projects or investigations carried out in NAB, NAPS and NAP. They provide, through experiments, a valuable means of revising ideas in a new context, involving the applications of chemistry and their social and economic effects. The Study is designed to take up 4 weeks towards the end of the course. Some schools show flexibility and tackle their Studies at the end of the first year sixth form so that students have practical experience of applied science in time to influence their choices in Higher Education.

50. NUFFIELD-CHELSEA CURRICULUM TRUST, Minutes of the nineteenth meeting of the Governing Body held at Chelsea College on 6 February 1984. NCCT Archive.

51. P.BLACK to B.FRASER, 30 March 1983. NCCT Archive.

52. NUFFIELD-CHELSEA CURRICULUM TRUST, A-level Physics Advisory Group. Record of a meeting held on 28 April 1980 at the Institute of Education, London. Harris Papers.

53. A.W.TROTTER, Nuffield A-level Physics Revision, An unpublished report for the NCCT, September 1980. Harris Papers.

54. ibid.

55. P.J.BLACK, In-service work in Birmingham, A letter to the Nuffield-Chelsea Continuation Committee, undated, EDU/52. Nuffield Foundation.

56. M.J.TEBBUTT, Teachers' views about the Nuffield advanced physics course, Phys.Educ., 16, 1981, 228-233.

57. M.J.TEBBUTT, Preliminary Report on Survey of Nuffield A-level Physics Teachers, prepared for the NCCT, August 1979. File NAP-1.

58. P.BLACK, Nuffield A-level Physics - universities' enquiry, An unpublished report for the NCCT, Undated. NCCT Archive.

59. Members of the Physics Advisory Group, 1980:

Professor K.F.Smith, Chairman, University of Sussex.
B.Brindle, Queen's School, Bushey.
Dr.Bridget Carter, Blandford, Dorset.
Professor R.Chambers, University of Bristol.
Mrs.J.Gell, London.
Dr.R.Hacket, Christ Hospital School, Horsham.
I.Kernaghan, Forest Hill School, London.
Dr.F.Mandl, University of Manchester.
I.Oldfield, The Netherhall School, Cambridge.
J.Ogborn, Chelsea College.
A.Trotter, Ilford.
Professor P.Black, Chelsea College.

60. NUFFIELD-CHELSEA CURRICULUM TRUST, op.cit. 52.

61. ibid.

At the next meeting of the Advisory Committee, held on 23 May 1980, members agreed to produce suitable A-level questions involving the use of algebra. In addition, position papers outlining changes and/or a revised structure were prepared:

Unit 1	R.Hackett and A.Trotter
Unit 4	J.Ogborn, I.Kernaghan and K.Smith
Unit 6	J.Harris and G.Foxcroft, commissioned
Unit 7	J.Gell and I.Oldfield using the N and F outline
Unit 8	I.Kernaghan
Unit 9	J.Ogborn with help from P.Black, R.Chambers and F.Mandl
Unit 10	R.Chambers and F.Mandl
General Framework	P.Black and J.Ogborn
Mechanics	A.Trotter

Unit 2 was not needed, and Units 3 & 5 were considered later.

62. NUFFIELD-CHELSEA CURRICULUM TRUST, Report to the NCCT of the A-level Physics Advisory Group, 3 November 1980. The final version of the report was agreed at a meeting held on 28 October 1980. Harris Papers.

63. REVISED NUFFIELD ADVANCED SCIENCE, Physics Examinations and Investigations, Published for the NCCT by Longman Group Limited (1985).

64. J.HARRIS, Revised Nuffield advanced physics, Phys.Educ., 20, 1985, 18-23.
See also the exchange of letters between K.D.FULLER and J.HARRIS, Phys.Educ., 20, 1985, 152-154.

65. Professor P.BLACK, op.cit. 27.

66. STANDING CONFERENCE ON UNIVERSITY ENTRANCE and THE COUNCIL FOR NATIONAL ACADEMIC AWARDS. A minimal core syllabus for A-level physic,. October 1980.
This report originated from a study by a working party convened by SCUE and the Standing Conference of Professors of Physics, under the chairmanship of Professor P.BLACK. In 1977 they published SCUE syllabus Studies No.4 (see Phys.Educ., 13, 1978, 255-258). Following the Government's decision to retain A-levels a new and larger working party was formed under Professor Mott to propose a core syllabus that allowed for variety, flexibility and innovation in the A-level syllabus as a whole.

67. Professor P.BLACK, op.cit. 27.

68. J.HARRIS, Revision of Nuffield A-level Physics, October 1981. A paper prepared for the first meeting of the Physics Consultative Committee held on Wednesday 25 November 1981 at the Institute of Education, London. Harris Papers.
The evidence was that not all schools had received Black's invitation.

69. Dr. JOHN HARRIS joined the staff at Chelsea College, Centre for Science Education, in 1968. Earlier, in 1964-68 he was a Research Associate in Education and a lecturer in Physics at Harvard University, where he helped develop Harvard Project Physics (for details see G.HOLTON, The Project Physics Course - Notes on its educational philosophy, Phys.Educ., 11, 1976, 330-335). Since the merger of King's and Chelsea Colleges at the Centre for Educational Studies, King's College, London (1984 90), he headed the physics section and the Science Unit. He has edited units of the Nuffield 13-16 Science project and was General Editor for the Revised NAP course.

70. Professor P.BLACK, op.cit. 27.

71. REVISED NUFFIELD A-LEVEL PHYSICS CONSULTATIVE COMMITTEE:
Professor K.F.Smith School of Mathematical and Physical Science, University of Sussex. Chairman.

W.F.Archenhold Centre for Studies in Science Education, University of Leeds.
W.Anderson NCCT Publishing Unit.
J.Bauser Inspector of Science, ILEA.
Professor P.J.Black Centre for Science and Mathematics Education, Chelsea College, London.
R.Hackett Christ's Hospital, Horsham, West Sussex.
J.Harris Centre for Science and Mathematics Education, Chelsea College, London.
W.Mace King Edward VII School, Sheffield.
R.Northage Beechen Cliff School, Bath.
J.Ogborn Centre for Science and Mathematics Education, Chelsea College, London
A.Parker Kingsbridge School, Devon.
M.Tebbutt Faculty of Education, University of Birmingham.
A.E.De Barr retired, formerly Head of Machine Tools Research Association.

72. J.HARRIS interview with K.D.FULLER, 5 January 1989.
J.Harris and W.Anderson prepared two samples of Students' Guide Material:
Model A (SMOOTH), a continuous text and the style that was eventually adopted for the Teachers' Guides.
Model B (CHUNKY), a compressed text with a margin for comments and diagrams, and this style is to be found in the published version.
John Harris wrote to all NAP teachers in November 1981, enclosing samples of Model A and B, and he requested comments and help for the revision.

73. NUFFIELD-CHELSEA CURRICULUM TRUST, A-level Physics Revision. Minutes of second meeting of the Consultative Committee, Saturday 13 February 1982 at Onslow Court Hotel, London. Harris Papers.
W.Anderson established two editorial roles for the revision: for completely new work the rate was £40 per 1,000 words, and for reworking the original course £20 per 1,000 words.

74. NUFFIELD-CHELSEA CURRICULUM TRUST, A-level Physics Revision. Minutes of sixth meeting of Consultative Committee, Saturday 19 February 1983 at Onslow Court Hotel, London. Harris Papers.

75. J.HARRIS to E.J.WENHAM, 16 November 1982. Wenham Papers.

76. E.J.WENHAM interview with K.D.FULLER, 4 August 1986.

77. J.HARRIS, op.cit. 72.

78. ibid.

79. J.OGBORN, Systems, control and measurement, A paper prepared for the A-level Physics Revision Consultative Committee. Undated. Harris Papers.

80. J.OGBORN and D.WONG, A microcomputer dynamic modelling system, Phys.Educ., 19, 1984, 138-142.

This work on dynamics was published as:

REVISED NUFFIELD ADVANCED SCIENCE, PHYSICS: Dynamic Modelling System Models, Longman Group Limited (1985).

A further five computer assisted learning units were developed by J.Harris, J.Sotillo, D.Creasy and D.Squires covering course topics: Simple harmonic motion; Gravitational field and potential; Electric fields; Quantum shuffling and Solving the Schroedinger equation. The work was published:

REVISED NUFFIELD ADVANCED SCIENCE, PHYSICS: Nuffield A-level Software Pack, Longman Group Limited (1985).

81. C.J.ADKINS, A national core syllabus for A-level physics, Phys.Educ., 16, 1981, 128-135.

82. J.HARRIS, op.cit. 64, p.19.

83. J.R.CRELLIN, R.J.J.ORTON and D.A.TAWNEY, Present-day school physics syllabuses, Rep.Prog.Phys., 42, 1979, 677-725.

84. J.HARRIS, Nuffield Advanced Physics: Revision. The length and content of the proposed revised course, May 1982. Harris Papers.

85. J.HARRIS, Reducing the course to a more manageable size. December 1982. Harris Papers.

86. NUFFIELD-CHELSEA CURRICULUM TRUST, A-level Physics Revision, Minutes of sixth meeting of Consultative Committee, Saturday 19 February 1983 at Onslow Court Hotel, London. Harris Papers.

87. M.MOORE to J.HARRIS, 16 July 1982. Harris Papers.

88. NUFFIELD-CHELSEA CURRICULUM TRUST, A-level Physics Revision, Minutes of seventh meeting of Consultative Committee, Saturday 7 May 1983 at Onslow Court Hotel, London. Harris Papers.

89. OXFORD AND CAMBRIDGE SCHOOLS EXAMINATION BOARD, Nuffield Advanced Physics Examination. Notes from meeting of Awarders and Representatives from Schools, November 1983.

90. P.J.BLACK to all teachers entering candidates for Nuffield Advanced Physics, 12 December 1983.

91. NUFFIELD-CHELSEA CURRICULUM TRUST, Governors' Report for the year ended 31 December 1985. NCCT Archive.

92. J.MILLER, Revised Nuffield Advanced Science. Physics. Units A to G., SSR, 67, 1985, p.411.

93. R.CHADWICK, Book Reviews: Revised Nuffield Advanced Science: Physics Students' Guide 1 - Units A to G., Phys.Educ., 21, 1986, 61-62.
94. E.J.WENHAM, op.cit. 76.

95. D.SELA, Teachers' and students' reactions to the Revised Nuffield A-level Physics Course (RNAP), a report prepared for the NCCT, Centre for Educational Studies, King's College, London(1988).

An abridged version of the report was published under the same title in Phys.Educ., Vol.25, 1990, 213-220.

Sela's teachers' questionnaire was sent to all 423 centres entering students for the 1988 RNAP examination. He received 110 responses relating to 189 teachers and about 2100 students, 25% of the total number who eventually took the examination.

96. ibid. pp.21-23.

Sela noted a tendency towards higher satisfaction with the new Teachers' Guides than with the Students' Guides.

97. ibid. p.17.

98 ibid. p.64.

99. OXFORD AND CAMBRIDGE SCHOOLS EXAMINATION BOARD (on behalf of G.C.E. Examining Boards), Syllabus Statement for A level Physics (Nuffield). Approved by the Secondary Examinations Council for examinations from Summer 1990 onwards. May 1988.

100. K.DOBSON, Proposed Revision of [Revised] Nuffield Advanced Physics, 5 May 1989.

The Nuffield Post-16 Physics Group met on 22 April 1989 to consider the establishment of a Nuffield Physics AS-level examinations and to review RNAP. The Group consists of four Awarders, Ken Dobson, Chairman, Helen Young, Robin Jakeways, John Knowles and Robert Northage, two teacher representatives, Rod Parry and Susan Ross, one representative from NCCT, John Harris, and one officer from the Oxford and Cambridge Board, Betty Fraser.

101. T.HICKSON, Nuffield A-level Physics - a new departure, Phys.Educ., Vol.26, 1991, 3-4.

102. NUFFIELD-CHELSEA CURRICULUM TRUST, Management Committee. Report of 66th meeting held on 15 May 1986 at King's College (Chelsea Campus). NCCT Archive.

103. R.LOCK, Choosing an A-level course, J.of Bio.Educ., Vol.21, No.2, 1987, p.77.
T.TURVEY, Nuffield Advanced Biology, J.of Bio.Educ., Vol.21, No.3, 1987, p.154.
R.LOCK, A-level Science Courses, Educ.in Sc., No.122, 1987, p.27.
T.TURVEY, Nuffield Advanced Science Courses, Educ.in Sc., No.123, 1987, p.23.

104. W.L.McKINNEY and I.WESTBURY, Stability and Change: the Public Schools of Gary, Indiana, 1940-1970, in Case Studies in Curriculum Change: Great Britain and the United States , W.A.REID and D.F.WALKER(Eds), Routledge and Kegan Paul(1975), p.11.

105. D.GEDDES, DES critics put Schools Council future in doubt, The Times, 3 December 1981.

106. M.WARING, Curriculum change and inertia, edited transcript of a talk given at the University of East Anglia, December 1983.

107. M.MADEN, England and Wales, in The School and the University, B.R.CLARK(Ed), University of California Press Ltd.(1985), p.93.

108. See for example:
M.ERAUT, Institution-based Curriculum Evaluation, and P.MITCHELL, Institutional Evaluation: the process within a school, in Evaluating the Curriculum in the Eighties, M.SKILBECK(Ed.), Hodder and Stoughton(1984), pp.54-70.
M.B.MILES, M.EKHOLM and R.VANDENBERGHE(Eds), Lasting school improvement, Leuren:Aggo(1987).

109. W.A.REID, Strange curricula: origins and development of the institutional categories of schooling, J.Curriculum Studies, Vol.22, 1990, 203-216.

110. T.JANSEN and R.van der VEGT, On lasting innovation in schools: beyond institutionalization, J.Education Policy, Vol.6, 1991, 33-46.

111. ibid. p.35.

112. EUROPEAN ECONOMIC COMMUNITY. The EEC's desire to establish a single market in 1992 will allow the free movement of goods and people throughout member states. There will be mobility of the workforce for all abilities. The NCVQ have recognized the importance of the European dimension (see: NCVQ, NCVQ and 1992, Update, No.1, 1989, p.5.). SEAC, too, has contacted the Education Ministries of EEC

states to discuss co-operation over final examination in schools, post-16 (see: SEAC, Recorder, No.4, 1990, p.9.).

113. B.R.CLARKE(Ed.), The School and the University, University of California Press Ltd.(1985), p.291.

114. Professor R.BECHER, communication with K.D.FULLER, 17 August 1989. File NAP 1.

115. NFSTP, Projects and Royalties, Paper No.E.68 12/3, Item No: 4. Undated. Nuffield Foundation.

116. THE HUMANITIES CURRICULUM PROJECT was Organized by Lawrence Stenhouse and jointly funded by the Schools Council and the Nuffield Foundation. The project was developed from 1967-72 and from 1970 was located at the University of East Anglia. See: A.ASTON, The Humanities Curriculum Project in Curriculum Research and Development in Action, L.STENHOUSE(Ed.), Heinemann Educational Books(1980), pp.139-148.

117. G.CASTON to K.KEOHANE, 18 August 1969. Keohane Papers.

118. W.ANDERSON, Nuffield Projects: the lessons of experience, 9 November 1984. NCCT Archive.

119. W.ANDERSON to K.KEOHANE, 12 October 1971. Keohane Papers.

120. W.ANDERSON, op.cit. 118.

121. P.J.BLACK, Some notes about the new project for the secondary science curriculum, 30 October 1980. ASE Archive.

122. G.TALL, The processes of curriculum development and evaluation, J.Curriculum Studies, Vol.21, 1989, 271-276.

123. Professor P.BLACK, op.cit. 27.

124. W.A.REID, op.cit. 109, p.205.

125. DES, National Curriculum Task Group on Assessment and Testing, DES (undated).

In July 1987, The Secretary of State, Kenneth Baker set up a Task Group, under Chairman Professor P.J.Black, to advise on assessment and testing within the National Curriculum. The Report was partly completed on 24 December 1987 and a further Three Supplementary Reports were submitted on March 1988. Professor Jack Allanson was one of the ten members of the Group.

P.J.BLACK, APU Science - the past and the future, SSR, Vol.72, 1990, 13-28.

126. J.SPICE, see reference 36 above.

127. J.HARGREAVES and T.HARGREAVES, Some Models of School Science in British Curriculum Projects, and their implications for STS [Science, Technology and Society] Teaching at the Secondary level, Social Studies of Science, Vol.13, 1983, 569-604.

128. M.J.LOADER, An 'experiment' into the comparability of A-level physics grades, 1980-82, SSR, Vol.65, 1984, 569-573.

129. D.SELA, op.cit. 95, p.7.
In his survey Sela found that RNAP school types were: Comprehensive 45%, Selective (Independent and Grammar) 35%, Sixth-Form College 13%, FE College 5%, Other 2%. These proportions are consistent with the Table 8, Chapter 4. Moreover, 82% of Sela's sample were co-educational schools, 14% boys' schools, 1% girls' schools and 3% unknown.

130 G.McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies of Science, Vol.18, 1988, 703-24.
G.McCULLOCH, Education for leadership in the 1950s: The Ideology of Eric James, J.of Educational Administration and History, Vol.XXI, 1989, 43-51.

131. M.J.MORAVCSIK, Is science elitist? A world-wide view, Phys.Bull., Vol.28, 1977, p.205.

132. SCHOOL MATHEMATICS PROJECT (SMP).
In order to establish an independent financial base for SMP, its founding Director, Bryan THWAITES, a former mathematics teacher at Winchester College and Professor of Theoretical Mechanics at the University of Southampton, approached the Nuffield Foundation for a grant of £24,900 to help establish the project. McGill and Becher met Thwaites in July 1962 but were unable to find sufficient common ground to proceed. As a result of this failure, Thwaites established SMP's financial autonomy within a charitable Trust which initially received grants from industry, the Leverhulme Foundation and payments from the publisher Cambridge University Press. However, the Nuffield Trustees decided to initiate their own junior mathematics project but, at the same time, continued to provide SMP with a number of smaller grants of £1,000 throughout its development period. Prudently, the Trustees hoped for 'informal association' between SMP and the NFSTP, especially at A-level.

133. P.J.BLACK, The Nuffield-Chelsea Curriculum Trust and the Examining Boards, 18 June 1980. NCCT Archive.

134. G.HOWSON(Ed.), Challenge and responses in mathematics. Essays to celebrate the twenty-fifth anniversary of the School Mathematics Project, Cambridge University Press(1987), p.80.

135. C.E.SWARTZ, Strong and Weak Interactions, Clifford E.Swartz's acceptance speech for the 1987 Oersted Medal, presented by the American Association of Physics Teachers, 30 January 1987, Am.J.Phys., Vol.55, 1987, 781-785.

136. THE NUFFIELD FOUNDATION TRIENNIAL REPORT, The 38th Report of the Foundation for the years 1986-8, The Nuffield Foundation(1989), p.10.

137. T.S.ELIOT, Little Gidding, [from Four Quartets, Faber and Faber, (Mcmxliv)] in The Penguin Book of English Christian Verse, P.LEVI (Ed), Penguin Books (1988), pp.327-334.

138 J.OGBORN, New hope for physics education, Physics World, October 1999, pp29-32.

CHAPTER 6 - REFERENCES and NOTES

1. P.J. BLACK, Pupils' attitudes to science, Studies in Science Education, Vol.4, 1977, 149-153.

2. J.M. ATKIN, The Government in the Classroom, University of London Institute of Education (1980).

3. L. FARRER-BROWN, Educational Research and Experiment, Paper F.115/1 prepared for the 115th meeting of the Trustees of the Nuffield Foundation, 8th December 1961, The Nuffield Foundation.

4. M. YOUNG, The schooling of science, found in G. WHITTY and M. YOUNG (Eds.), Explorations in the Politics of School Knowledge, Nafferton Books (1976), pp.50-52.

5. G. McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies of Science, Vol. 18, 1988, 703-724.

6. B.M. JENNISON, Eric Rogers, 1902-90, Physics World, September 1990, p.65.

B.M. JENNISON and J.OGBORN (Eds), Wonder and Delight, Essays in Science Education in honour of the life and work of Eric Rogers 1902-1990, Institute of Physics (1994).

7. B.E. WOOLNOUGH, Physics Teaching Schools, 1960-85: Of People, Policy and Power, The Falmer Press (1988).

G. McCULLOCH, E. JENKINS AND D. LAYTON, Technological Revolution? The Politics of School Science and Technology in England and Wales Since 1945, The Falmer Press (1985).

8. A.D.C. PETERSON, Three Decades of Non-reform, Oxford Review of Education, Vol.14, 1988, 127-137.

9. NUFFIELD FOUNDATION, Science Teaching Projects, Expenditure until 1963 and estimates for 1963-4, 1964-5, Paper F.134/6 prepared for the Trustees' 134th meeting held on 20 March 1964 at Nuffield Lodge, Nuffield Foundation.

Initially £100,000 had been set aside for NOP and at this meeting an extra £55,000 was made available for the project.

10. G. McCULLOCH, op. cit. 5, p.715.

11. D. LEE to B. YOUNG, 18 December 1964. Spice Papers.

12. SCHOOLS COUNCIL, Sixth-Form Curriculum and Examinations, Working Paper No.5, HMSO (1966). As it turned out the schools were not yet ready for such reforms and they rejected Lee's proposals as set out in Working Paper No.5. Later, various other attempts to broaden the sixth-form curriculum were proposed throughout the time-span of this curriculum history of NAP, and they all failed. Excellent summaries are found in:

D. LAWTON, Education, Culture and the National Curriculum, Hodder and Stoughton (1989), pp.74-79.

A.D.C. PETERSON, op. cit. 8.

13. D. HODSON, Social control as a factor in science curriculum change, Int. J. Sci. Educ., Vol. 9, 1987, 529-540.

14. NAB was the first project to present its intentions when, in November 1965, they widely distributed their booklet Aim and Outline Scheme in a deliberate attempt to secure good public relations. Similarly Coulson (NAC) and Spice (NAPS) were very good at widely distributing their clear policy and syllabus papers, especially to SCUE and to members of the A-level Joint Consultative Committee. Allanson, in particular, was impressed by their actions.

15. R. PARRY, D. HENDERSON, L. WHITE, P. NORTHCOTT, S. TAYLOR, Lean physics, letter in The Times Educational Supplement, 24 June 1988, p.21.

In this letter these five physics teachers point out that the NAP course meets so many of the Higginson recommendations, and questioned whether the Higginson Committee were even aware of its existence. The teachers, of course, were unaware of the limits imposed on the Committee in that it could not comment on inividual A-level syllabuses or courses, not even to indicate good practice.

16. P.J. FENSHAM, The Time Factor in Curriculum Development, J. Curr. Studies, Vol.3, 1971, 179-183.

17. R. LOCK, A history of practical work in school science and its assessment, 1860 1986, SSR, Vol. 70, No.250, 1988, 115-119.

R. LOCK, Open-ended, problem -solving investigations. What do we mean and how can we use them?, SSR, Vol.71, No.256, 1990, 63-72.

B.E. WOOLNOUGH, The Making of Engineers and Scientists, Factors Affecting Schools Success in Producing Engineers and Scientists, The Summary Report, Oxford University Department of Educational Studies (1991), p.30.

18. S. JOHNSON, Beloe to Baker: Thirty years of teacher assessment and moderation, Midland Examining Group, January 1990.

19. M. KINGDON, The Reform of Advanced Level, Hodder and Stoughton, 1991.

20. P.J. KELLY, A reappraisal of Examinations, J. of Curr. Studies, Vol.3, No.2, 1971, 119-127.

21. E.M. ROGERS to E. WENHAM, 5 November 1965. Wenham Papers.

22. P.J. BLACK, Report to the Nuffield-Chelsea Curriculum Trust of the A-level Physics Advisory Group, 3 November 1960, NCCT Archive.

23. Professor J. OGBORN, interview with K.D. Fuller, 15 February 1991.

24. J. OGBORN, Ideas about the course [NAP] as a whole, a paper prepared for the Physics Advisory Group, undated, Harris Papers.

25. ibid.

26. J. HARRIS, interview with K.D. FULLER, 5 January 1989.

27. M. YOUNG, op. cit. 4, p.49.

28. M. KINGDON, op. cit. 17, p.76.

29. M. WARING, The Implementation of Curriculum Change in School Science in England and Wales, Eur. J. Sci. Educ., Vol.1, 1979, 257-275.

30. L. FARRER-BROWN, op. cit. 3.

Appendix 1

Paper F 115/1

Educational Research and Experiment

Paper prepared by Leslie Farrer-Brown for the 115th Meeting of the Trustees of the Nuffield Foundation, Friday 8 December 1961.

PAPERS ANNEXED TO THE MINUTES OF THE HUNDRED AND FIFTEENTH MEETING

Paper F. 115/1 *(See Minute IV.* 1209)

EDUCATIONAL RESEARCH AND EXPERIMENT

A. *Evidence of need*

1. The Crowther Report in 1959 drew attention to 'the inadequacy of the tools that lie to the hand of the educational planner 'in this country'. Section 697 of the Report continues:

> " ... There are the most extraordinary gaps in our knowledge of what goes on in the schools and technical colleges we have today, let alone in the minds of their pupils. The Ministry's statisticians are constantly in the position of being asked to make bricks without straw. Other countries are wrestling with the same problems as ourselves and, some of them, finding interesting solutions to them; but our knowledge of what they are doing rests far too much on the subjective basis of returning travellers' tales. When one moves from what is to what might be - the proper field of research - the absence of information is even greater. In view of the very large sums of money that are spent on education every year, the expenditure on educational research can only be regarded as pitiable. If there is to be a consistent programme of educational development, almost the first step should be to review the provision for statistics and research."

2. More recently, the Parliamentary and Scientific Committee, in a memorandum to the Minister for Science, the Minister of Education, and the Chancellor of the Exchequer, gave more detailed substance to these criticisms:

(i) National expenditure on education in Great Britain in 1960 was £800 million (approx.). Decisions as to how this sum is to be spent, and estimates as to future needs are made on informed guesswork rather than established fact. Nothing has been built into new educational schemes whereby to assess their success. Still less are alternatives submitted to rigorous tests. Furthermore, there appears to exist no means of feeding back information gained from the research carried out to the authorities able to apply the results of research.

(ii) Expenditure in Great Britain on empirical research into education and its achievement does not exceed £125,000 annually: a mere 0.014 per cent. of the total!

The Committee pointed out that research into medicine, agriculture, and industry was on a vastly more generous scale;[1] they recommended the setting up of an Educational Research Council (analogous to the M.R.C., A.R.C., and D.S.I.R.) to encourage a rapid expansion of empirical research into educational problems.

B. *Existing Resources*

1. Apart from the National Foundation for Educational Research (with a 1959-60 budget of £32,559*)* and the Scottish Council for Research in Education (1959-60 budget £8,338)**,** there are no formal organizations devoted primarily to research.

2. The twenty-six university departments of education in Britain concentrate mainly on teacher training, but also run a certain number of (mainly part-time) research projects. They account for seventy-one current studies; but these are largely local and uncoordinated. In the view of the Parliamentary and Scientific Committee the total output from this source would not be equivalent to 100 full-time workers.

3. Postgraduate degree students contribute 121 of the total of 233 known empirical studies now being carried out. In the whole country there are ten paid research fellowships in the subject; Edinburgh University has by far the largest fund, about £5,000 a year.

4. Individual teachers and Local Education Authorities contribute in a small way (three current teacher group studies and two L.E.A. projects); they do not have adequate resources to carry out long-term or large-scale work, and usually lack skilled advice on experiment design and statistical analysis.

C. *Comparison with other countries*

1. Our lack of knowledge of the work being done abroad is one more symptom of the paucity of educational research the United Kingdom. There is no central source of information about, for instance, the French language research at St. Cloud or the new unified Mathematics course for American High Schools: 'our knowledge . . . rests far too much on the subjective basis of returning travellers' tales'.

2. On the basis of these travellers' tales, however, one has the impression that there is a livelier awareness in Europe and America of the need for educational research. Russia's school curricula are very carefully prepared, on a national scale, by the Academy of Pedagogical Sciences; in Sweden's new schools there are built-in checks on the efficiency of the system; a vast and costly scheme of research has

1. Excluding D.S.I.R. grants, the Committee estimated that industry spends annually over £300 million on research - 4 per cent. of its £7,500 million contribution to the gross national product.

been launched in the United States by the Ford Foundation, and American school science courses are being reformed under the National Science Foundation. It is difficult to believe that France, Switzerland, and Italy (who have produced educationists of the calibre of Binet, Piaget, and Montessori) are inactive in the field.

D. *Plans for immediate action*

1 It seems unlikely that the Parliamentary and Scientific Committee's recommendation to set up an Educational Research Council will be adopted at present: the scale of current work and the supply of qualified research workers would hardly justify it.

2 It may be asked why the solution proposed by a leading article in *The Times Educational Supplement* is not adopted: to make a more generous appropriation to the National Foundation for Educational Research. This body might indeed form the nucleus of a larger organization in the future: it is probably not capable of being much expanded at present, though larger grants have been promised by the Minister. As far as can be foreseen, the N.F.E.R. will continue to act as an advisory centre and a clearing-house of ideas rather than primarily as a sponsor of large-scale and costly new projects.

3. However, the Ministry of Education are clearly aware of the need to stimulate research, and have set up a small branch, which is solely concerned with this. Some informal approaches have already been made by them to the Foundation.

E. *T*he *part played* by the *Foundation*

1. The trustees have shown their continuing determination to implement sections (ii) [' … the organization, development, and improvement of technical and commercial education including the training of teachers … '] and (iv) [‘the advancement of education’] of the Trust Deed. The various research schemes the Foundation has supported, over the years, do not fall into any rigid pattern; but they may be roughly classified under four headings: general surveys; sociological studies; psychological studies; and curricula and teaching methods. The grants made so far add up to nearly £300,000. A brief account of each relevant scheme is set out in the Appendix; some of the main items in each category are now mentioned briefly in turn.

2. *General Surveys.* The Foundation has not so far sponsored any broad inquiries into the school system: but there have been a number of surveys of university, technical, and adult education. Examples include the Furneaux study of university selection methods, and the Foundation Year survey at North Staffordshire; the Birmingham assessment of ‘sandwich courses’ and the two current investigations of mathematics in technical training; the Trenaman research into education from mass media, the Groombridge study of education in retirement, and the present Liverpool study of adult education in its historical and social context.

3. *Sociological studies*. The Foundation has supported a number of studies of the people most intimately concerned with education: the pupils and the teachers. There have been, for instance, grants to the Scottish Council for Research in Education for various follow-up studies arising from their mental survey of 11 year olds, and to Birkbeck College for an examination of the attitudes and aspiration, of school children; the Institute of Education were helped to undertake an extensive inquiry into the social characteristics and status of the teaching profession, and the Sheffield School of Sociology is currently investigating wastage among women teachers.

4. *Psychological studies.* The main body of 'Foundation schemes has concerned (i) visual aids (notably Oversea Visual Aids Centre and Centre for Educational Television Overseas;[1] and the earlier Reading study of the basic efficiency of visual presentation), and (ii) the process of learning to read (including the current Institute of Education inquiry, and the National Book League survey of books for backward readers).

5. *Curricula and teaching methods.* The Foundation has so far concentrated on science (e.g. the Manchester experiment in part-time school teaching by research students, the recent Battersea Conference on school physics, and - not least - the Unit for the History of Ideas) and on language teaching (e.g. the Leeds and East Ham experiments in French for 11-year olds.)

F. *The pattern for the future*

1. Some future projects will arise as logical extensions of earlier studies: there are likely, for instance, to be approaches from technical colleges for further research schemes, and requests from schools and other institutions for help towards new developments in language teaching.

2. Other projects may arise from current academic interests. The techniques of intelligence testing have been under scrutiny by educational psychologists, and some schemes for fundamental research in this subject may be drawn up within the next year or so. Again, mathematics teaching is a lively subject at the moment (witness the recent O.E.E.C. report, *New Thinking in School Mathematics*, and the 1961 Southampton Mathematical Conference proceedings, *On Teaching Mathematics*); it seems probable that proposals on this topic may come before the trustees soon.

3. Long-term proposals which the trustees have under review include a possible study of child development and behaviour, and the setting up of a group to assess the educational problems of technical colleges (the trustees have expressed particular interest in this).

G. A suggested general programme

1. The trustees might wish to consider the role which these past and present investigations could play in a general Foundation programme of educational research and experiment. There are some gaps to fill and some basic questions still to be answered in detail; and when the answers are available there may well be some important practical steps which the Foundation

1. One of the aims of these organizations (but not the principal one) is to promote research.

- matching action to discovery -could take.

2. *General surveys*. It was noted earlier (E.2 above) that there have been no Foundation grants towards inquiries into the school system. Yet the relative advantages of comprehensive, unilateral, and other organizational systems must be studied carefully if we are to have a firm basis for future educational planning. The role of the public schools has been debated, and some valuable investigation might be done here. Comprehensive schools are this year being inspected by the Ministry for the first time; on any long-term project much useful information may become available from H.M. Inspectors.

3. *Sociological studies*. There is much speculation, but little research, on the effects of examinations on children (and in particular the 11-plus test, the G.C.E., and university scholarships). It would also be valuable to investigate, for instance, what is the largest size of class in which a particular subject could effectively be taught to a particular age group, and what student-teachers find most helpful and least beneficial in their training courses (with a particular view to revising such courses, about which there is a good deal of criticism).

4. *Psychological studies*. What are the right stages in a child's development for the introduction of new concepts? Can the findings of Piaget and others be put to practical use in deciding the best time, e.g. to begin teaching French, to introduce atomic theory, to start on variables or on irrational numbers in mathematics? (J. Z. Young's analogical studies of human learning may in the long run help to answer such questions.) Again, can the value of visual aids be demonstrated and assessed by experiment? It is widely held that films, film strips, television, and other aids to teaching produce a more rapid understanding. Yet the study by Vernon and Laner at Reading (see E.4 above) has questioned this assumption as far as mechanical skills are concerned. Vernon and Laner concluded that such methods *unless used in a particular way at a particular stage in learning* had little positive advantage. Is this true of visual aids in general?

5. *Curricula and teaching methods*. (i) What are the advantages of certain teaching techniques over others? Could controlled tests be set up to compare, for example, language teaching by new and by classical methods?

(ii) Similarly, what are the advantages of certain ways of ordering and presenting a subject over others? The Science Masters' Association has this year published new examination syllabuses for school physics, chemistry, and biology; the recent work on a unified mathematics course has been referred to in F.2 above. Can the results of these new courses be matched with the results of older curricula, and their effectiveness so demonstrated?

(iii) What is the extent of the need for classroom and laboratory apparatus and demonstration material? Are British science teachers, for example, hampered by the absence of good, cheap, commercially produced equipment? In Russia and Germany the central authorities ensure that the schools have an adequate supply of (sometimes quite elaborate) models for demonstrating crucial experiments. Perhaps we should study, as a matter of urgency, whether similar provision should be made in this country.

6. *Practical follow-up action*. The Parliamentary and Scientific Committee's memorandum (referred to in A.2 above) remarks that 'there appears to exist no means of feeding back information gained from the research carried out to the authorities able to apply the results of research'. One crucial question, then, concerns how best to use the information derived from some of the schemes already mentioned. It here that the Foundation is in an unusually fortunate position. Although some of the larger-scale inquiries would demand nation-wide action by the Ministry (and this underlines the importance of close collaboration with them), there are many spheres in which the Foundation's own resources could be used for pioneering measures linked with research findings. For example, it could support the writing of teachers' handbooks and textbooks along fresh - but experimentally well-founded - lines; it could finance the provision of teaching aids (including demonstration apparatus) to support the revised curricula; and it could make some provision for training teachers and future teachers in the new syllabuses and methods.

H. *Conclusion*

1. The previous sections have suggested the need for further research and the paucity of existing resources (especially in comparison with those of other countries). A brief review of the contribution the Foundation has made (and is making) has thrown up some positive suggestions for study and sub-sequent action. But if the Foundation's work is to be extended, it may perhaps be fruitful to embark on a general programme of educational research and experiment, and to make this one of the major aims of the next quinquennium.

2. In particular, the trustees may wish to consider whether the Foundation should collaborate with the Ministry of Education in calling a conference[1] - or setting up a temporary organization - to promote and give direction to educational research and (even more important) to translate its findings into practical terms.

3. Finally, the fundamental problem is likely to be one of manpower. If there is a scarcity of qualified research workers, perhaps the main aim should be to improve (or where necessary initiate) the research activities of university departments of education. This may be a propitious moment to lay down a lively tradition of educational research in the new universities, as well as to build one up in the old; the trustees may therefore wish to discuss a possible system of endowments, grants, and scholarships directed to this end.

1 This might follow the lines of the successful Biology Conferences held under the Foundation's auspices in 1950 and 1952.

APPENDIX

NUFFELD FOUNDATION GRANTS FOR RESEARCH IN EDUCATION

A. *General surveys*

1. University of education

University of London, Institute of Psychiatry: grants totalling £27,928 for the ten-year study undertaken by Mr. W. D. Furneaux, under the direction of Professor Sir Aubrey Lewis, into the value of psychological tests, as compared with normal academic tests, for predicting performance at universities and later in life. Mr. Fumeaux's findings were published this year in *The Chosen Few (O.U.P.).* A second volume is now in preparation which will present a study of university examinations, the way 'in which psychological tests can increase our understanding of the determinations of performance in such examinations, and thus of the ways in which such tests can legitimately be used as aids to selection.

University College of North Staffordshire: £5,000 towards the cost of an examination of the Foundation Year course to be conducted by Professor W. A. C. Stewart, acting-principal and professor of education, with the purpose of establishing what relationship there may be between performance in the Foundation Year course and such factors as previous educational record, subsequent performance in the degree course, career after graduation, etc.

University of Leeds, Brotherton Library: £2,068 for a one-year pilot survey of the pattern of book borrowing at the Library of the University of Leeds undertaken by Mr. P. E. Tucker, under the direction of the librarian, Mr. B. S. Page. A report on the study was published in *The Journal of Documentation,* March 1959, Vol. 15, pp. 1-11.

University College, London: Student Health Association: £100 to cover the cost of a two-day informal working conference on student performance, arranged by Dr. Nicolas Malleson, physician in charge of the Student Health Association, and under the chairmanship of the late Lord Stopford of Fallowield.

2. *Technical education*

Brunel College of Technology: £15,000 over three years for a programme of research into technical education and attitudes to work, to be carried out in the Department of Management and Production Engineering by Dr. Marie Jahoda, under the direction of Mr. R. A. F. Harcourt.

University of Birmingham, Institute of Education: £ **12,000** over five years for the establishment of a research unit in the Institute of Education under Professor E.A. Peel to study and advise on the placement, counselling, and teaching of part-time technical college students. The unit is headed by Dr. **Ethel C.** Venables.

Birmingham College of Advanced Technology, Department of Industrial Administration: £6,700 over two years for a pilot investigation, directed by Dr. T. Lupton, head of the Department of Industrial Administration, of existing arrangements in the spacing of industrial and college training, and for the subsequent collecting and analysing of views and opinions about them.

Loughborough College of Technology: £500 to enable Mr. R- L. Cannell, vice-principal of the college, to accompany Mr. E. R. L. Lewis, controller of education for the English Electric Group of Companies, on a visit to the United States, for approximately two months, to make a critical analysis of the relationship in the United States between academic education in colleges and practical training in industry for professional engineers.

Royal Technical College, Salford, Department of Mathematics: £5,500 over approximately fifteen, months, for an investigation of the use of mathematics in the electrical engineering industry. The team, under the direction of Dr. E. Kerr, head of the Department of Mathematics, will study the implications of its factual survey and make recommendations on the methods of teaching and on the appropriate syllabuses for students in the electrical engineering fields.

National College of Rubber Technology: £500 to enable Dr. N. H. Langton, senior lecturer at the College, to undertake an investigation into the teaching of mathematical topics to students of high polymer technology. The results of the study will be embodied in a report which it is hoped will become a textbook for students and teachers of the science and technology relating to rubber, and of other technologies.

3. *Adult education*

University of Liverpool, Department of Extra Mural Studies:£6,650 over two years to assist Dr. T. Kelly, Director of Extra-Mural Studies, who is carrying out an investigation into adult education and social change during the past half-century. Dr. Kelly has appointed Dr. John Lowe as a senior research fellow, to undertake a general review of the nature and extent of adult educational provision at the present time.

National Institute of Adult Education: £3,020 for support of an inquiry into educational provision for middle and later life, carried out by Mr. Brian Groombridge. The results of the inquiry were published by the institute, in *Education and Retirement,* National Institute of Adult Education, 1960.

Mr Joseph Trenaman: £1,967 over approximately three years for a study of the attitudes of people from different backgrounds to educational material presented by the organs of mass communication- radio, TV, the press, and films. Mr. Trenaman has tried to assess how these could meet educational needs, and what levels of comprehension and resistance they are likely to encounter. The results of his research are to be published, in a form suitable for the general reader, next year.

B. *Sociological Studies*

1. *School teachers*

University of London, Institute of Education: £9,750 Over three years to enable Mrs. Jean Floud, a senior lecturer in the sociology of education, to direct an inquiry into the social characteristics of the teaching profession in England and Wales.

University of Sheffield, School of Social Studies: £3,700 towards the cost of an inquiry into the wastage, after training, among women teachers in England and Wales which is being conducted by Mr. R. Kelsall, head of the School of Social Studies.

2. *School children*

The Scottish Council for Research in Education: grants totalling £22,000 over fifteen years towards follow-up studies of the trends of intelligence in Scottish school children. The results of these studies are about to be published by the Council in *The Level and Trend of National Intelligence*, which has been prepared for publication by Mr. J. Maxwell.

University of London, Birkbeck College, Department of Psychology: £2,500 over two years to support Professor C. A. Mace's investigation into the aspirations of school leavers. The results of this inquiry are to be published shortly.

C. *Psychological studies*

1. *Visual aids*

Oversea Visual Aids Centre: £40,000 over six years towards setting up and operating for an initial period a centre which could give practical service as well as contribute to a wider understanding of the aids that are available and their most effective use. H.M. Government has contributed a similar amount.

University of Reading, Department of Psychology: two grants totalling £4,210 over five years to enable Dr. M. D. Vernon and Mr. S. Laner (i) to carry out a research project into the nature of the processes by which information and instruction are conveyed by visual means, and (ii) to develop visual aid research. Articles on this work by both Dr. Vernon and Mr. Laner have been published in various journals - *Nature*, *The Journal of Education, Quarterly Journal of Experimental Psychology, British Journal of Psychology.*

(See also under Association for Teaching Aids in Mathematics, below.)

2. *Reading and learning*

University, of London, Institute of Education:
£14,000 over six years in support of a research programme, under Mr. John Downing, on the relationship between infants' experiences in learning to read and their intellectual and emotional development.

The National Book League: £3,000 over three years towards the cost of a scheme to assist in the Provision of suitable reading material for adolescent and young adult backward readers. As a basis for this inquiry, an exhibition was organized this summer, of a collection of such books already in existence which had been selected and grouped by Mr. S. S. Segal, Chairman of the Guild of Teachers of Backward Children.

The Guild of Teachers of Backward Children: two grants totalling £740: (i) £240 to cover the publication costs of the Guild's quarterly journal, *Forward Trends*, for 1958 to enable the Guild to expand its membership so that the journal could in future be self-supporting. (ii) £500 to enable the Guild to print a report of its internal conference on the backward child to serve as a textbook for teachers in special schools. This report was published in a special issue of *Forward Trends,* 1960.

3. *Mental testing*

University of Oxford: Mr. J. P. Corbett: £1,000
to enable Mr. J. P. Corbett to undertake research concerned with the logical analysis of the techniques of mental testing, and of the theoretical structures which have been built upon them.

(See also under Scottish Council for Research in Education, above.)

D. *Curricula and teaching methods*

1. *Science*

Nuffield Foundation Unit for the History of Ideas: £60,000 over three years for the establishment of a unit, under the direction of Dr. Stephen Toulmin, former professor of philosophy at the University of Leeds, to produce educational films and books. A series of books by, Dr. Toulmin and Dr. June Goodfield is being published, under the general title 'The Ancestry of Science', and these will cover the same ground as the films.

The Royal Institute of Great Britain: £3,000 over one year towards the development of the Royal Institution as a centre for school science teachers, so giving them chance to meet together and acquaint themselves with recent scientific advance.

Queen's University of Belfast, Department of Economics: £950 to enable Mrs. J. M. Alexander to complete her investigation, under the direction of Professor C. F. Carter, of the factors which affect the supply and training of scientists. The published material formed part of the Science and Industry Committee's report, *Science in Industry* (O.U.P., 1959).

University of Manchester, Department of Physics: £40,000 to enable Professor Samuel Devons to offer grants to up to six young physicists a year. These grants enable them to combine part-time university work with part-time science teaching at local grammar schools.

Battersea College of Technology, Department of Physics: £300 to cover the cost of a 5-day residential meeting at the College, arranged by Dr. L. R. B. Elton, head of the Department of Physics, to consider policy and future action in regard to the proposed revision of syllabuses and teaching methods for 'O' level and 'A' level physics.

2. *Mathematics*

Association for Teaching Aids in Mathematics: £290 to enable Mr. T. J. Fletcher. director of the

Association's film unit, to buy equipment to make mathematical films and to carry on research into the production of three-dimensional animated mathematical diagrams. Three of Mr. Fletcher's films, 'Resonant Cavities', 'Tangency' and 'Four-Point Conics' are now in circulation.

(See also under National College of Rubber Technology and Royal Technical College, Salford above.)

3. *Languages*

Experiments in teaching French: £1,500 for two experiments: (i) in three primary schools in East Ham where the teaching of French, under the direction of Mr. S. R. Ingram, senior modern language master at the East Ham Grammar School for Boys, has been introduced by audio-visual methods in the interval between the children taking the 11-plus examination in February and the end of the school year in July. (ii) at the Talbot County Primary School in Leeds, where under Mrs. M. Kellermann a group of about twenty boys and girls - during the same interval between taking the 11-plus and the end of the school year - have done all their lessons in French, as if in a classroom of a French lycée.

Appendix II

Paper F.115/2 11115/2

The Teaching of Science and Mathematics

Paper prepared by Leslie Farrer-Brown for the 115th Meeting of the Trustees of the Nuffield Foundation, Friday 8 December 1961.

Paper F. 115/2 [*See MinuteIV. 1209*]

THE TEACHING OF SCIENCE AND MATHEMATICS

A. *Introduction*

The plight of scientific education in Britain and the need for comprehensive reform have recently been much discussed. In this respect, the Crowther Report (1959) was not so much a voice crying in the wilderness as an introductory recitative to a large scale oratorio.

In their annual report for 1959-60, the Advisory Council on Scientific Policy wrote:

> 'We have no doubt that school science curricula are in need of a thorough re-examination. They tend at present to be unimaginative and to be overloaded with factual material (in part as a result of the tendency to keep adding new material without removing the old). It has been suggested to us that up to 20 or 25 per cent, of the content of the curricula in physics, chemistry and biology could be removed without any harm - and indeed with benefit. Mathematics curricula are equally in need of revision.'

In 1958 to 1959 a systematic review of existing science and mathematics 'A' level syllabuses was carried out at Birmingham University (under the auspices of the Gulbenkian Foundation) and detailed recommendations were made, in the belief that the emphasis should be on testing theoretical understanding rather than factual memory. International conferences, organized by O.E.E.C., were held in 1959, 1960, and 1961 to consider the science teaching problems common to all member countries; useful and detailed reports of these conferences were issued. In the United States, university teams working on a 'crash' programme under the auspices of the National Science Foundation produced an impressive series of high school and college science textbooks and teachers' handbooks.

Meanwhile, committees of the Science Masters' Association and the Association of Women Science Teachers had since 1958 been busy drawing up completely new school curricula embodying modern ideas and topics of current interest. The S.M.A./ outline syllabuses in chemistry, physics, and. biology were published earlier this year, and were in general well received.

B. *Assumptions*

On the understanding that the trustees might wish to associate themselves with these new trends in the teaching of science, the officer's of the Foundation have taken an active interest in recent developments. The Foundation's contacts were usefully extended at the Science Teaching Dinner held at Nuffield Lodge on 26 July. The Director has now arranged a further discussion with Dame Mary Smieton and other representatives of the Ministry of Education on 11th December. It would be valuable at this meeting to have the trustees' views on the plans which are now beginning to take shape. Accordingly, the assumptions which underlie the various topics to be discussed are in this preliminary section made explicit.

1. If the Foundation is to engage itself in the advancement of science teaching, it should do so on a large scale. Funds of up to £250,000,would not seem excessive for a project of such, urgency and importance.
2. If the Foundation participates on a large scale, it should do so actively; that is, it should not function solely as a grant-giving body, but should be an equal partner in the planning and operation of the exercise as a whole.
3. As far as possible, the various parts of the exercise should be closely interrelated; there should be an overall pattern and co-ordinated objectives.
4. But while the strategy should be comprehensive (and every scientific subject at every educational level should lie within the broad scope of the campaign), the tactics should be opportunist,(the initial attacks should be concentrated on certain key areas, and not dissipated along the whole front at once).
5. A sound knowledge of science is today a basic educational necessity for every child, whether or not he later intends to become a science specialist. Therefore the greatest need is to devise a satisfactory 'core subject' syllabus - in effect, an 'O' level course which can give the majority of children some insight into scientific thought and method (this was described in the Crowther Report, §413, as 'one of the most urgent tasks that confronts the schools today').
6. Granted an initial emphasis on courses up to 'O' level, the syllabuses already devised by the S.M. A./A.W.S.T. - which are generally agreed to be satisfactory - should form the basis of the attack.
7. Given an acute shortage of suitably trained. teachers, and scant opportunity for refresher courses. the new syllabuses - if they are to be widely adopted - will need very full documentation. It will be necessary to provide teachers' handbooks, laboratory notes, textbooks, demonstration equipment, and visual aids for the new syllabuses in each subject[1].
8. Thought and action along these lines is already more advanced in some subjects than in others. The spearhead of the campaign should be in 'O' level physics, where most work has been done; but chemistry and biology should meanwhile be actively softened-up for attack.
9. Such attempts to improve 'O' level teaching should not, however, be allowed to exclude equally pressing reforms at other levels. In particular, it may be thought important to inculcate a satisfactory attitude and approach in the earliest years. Therefore, science at the primary school should also be given particular attention.
10. No mention has so far been made of mathematics teaching. Yet the staff shortages are, if anything, more crucial, and the needs for curricular reform more drastic. Furthermore, the successful teaching of the exact sciences is heavily dependent on the understanding of mathematical notions. The teaching of mathematics should therefore be regarded as an integral part of the whole project.

On the basis of these assumptions, the following sections will consider in outline five major topics in the projected programme of science teaching: 'O' level physics; 'O' level chemistry; school biology; primary school science; and mathematics.

1. The S.M.A./A.W.S.T. have submitted proposals in this general spirit (see Paper F. 11 5/20) for subsequent consideration under item 28).

C. *'O' level physics*

In April 1961, assisted by a grant of £3000 from the Foundation, a conference on the teaching of modern physics was held in Battersea College of Technology. Interested teachers from a wide variety of schools discussed means of implementing the modern physics section of the new S.NLA./A.W.S.T. syllabus, and put forward their own views on method and presentation. From the wide interest shown in this conference, it became clear that the time for change was opportune.

During the summer, the Institute of Physics and the Physical Society set up a national committee on physics education under the chairmanship of Professor N. F. Mott. The committee as a whole is concerned as much with courses at sixth-form level (and their integration with university work) as with 'O' level physics; however, Professor Mott and the Deputy Secretary of the Institute (Mr. Norman Clarke) have, in discussions with the Director, shown themselves particularly anxious to further the teaching of science to non-specialists.

It seems preferable that any action the Foundation takes in connexion with school physics should involve the co-operation - or at least have the positive approval - of both the Mott committee and the S.M.A.. It is suggested that, ideally, the physics project should be under the whole-time direction of an eminent physicist (of the calibre of, for example, Sir Basil Schonland) with the backing of a small consultative committee (consisting of at least two school an two university teachers) chosen jointly by the Foundation and Mott committee, it being recognized that the director should have the fullest authority and freedom. If, however, a suitable individual director cannot be found, the project might (as a second best) be directed by the small committee itself

Some relevant work is already in progress in various parts of the country. For example, Mr. John Lewis, the senior science master at Malvern, is working on demonstration apparatus for the teaching of modern physics, with the full support of the S.M.A. and the Ministry of Education. The trustees may perhaps wish to associate themselves with this work and with any similar enterprises, as a prelude to more comprehensive and large-scale action.[2]

D. 'O' *level chemistry*

Much attention has been devoted to the modernization and improvement of school chemistry syllabuses; and the importance of establishing close links with physics teaching - especially in the introduction of atomic structures - has been emphasized. However, apart from the ***S.M.A.,*** no other body has officially identified itself with practical action in this field.

The Education Officer of the Royal institute of Chemistry is known to be interested in furthering the plans of the S.M.A. (perhaps along lines similar to those taken by the institute of Physic's). Informal discussions have already taken place between Mr. D. G. Chisman (the Education Officer of the Institute) and the Foundation.

It is thought that the trustees may wish to select 'O' level chemistry as the second prong of their attack, but that some useful experience might first be gained in work on the physics syllabus.

E. *School biology*

While the S.M.A. syllabuses in chemistry and physics have met with very little criticism, there are signs of dissatisfaction among the biologists: it is thought by many that the changes in the S.M.A. biology syllabus are neither sufficiently radical nor sufficiently imaginative. In these respects the Gulbenkian's Birmingham proposals are held to be preferable.[3]

It may therefore be proper to abandon, or considerably modify, the S.M.A.'s programme in this subject. Since, moreover, the teaching of biology is in a greater state of flux at all academic levels, the trustees may wish to precede action with further and more systematic research.

In this connexion, the department of education and the department of biology at the University College of North Staffordshire have been working jointly on a scheme for reviewing the teaching of biology from the age of seven to the age of twenty-two, with particular attention to methods of presentation at each stage. The Nature Conservancy is taking a close interest in this scheme, especially in connexion with field studies in biology.

It is suggested that the best approach to the teaching of biology at all levels may be via the North Staffs, investigation. Professor Stewart and some of his colleagues are to discuss future possibilities with the Director on 6th December: a report on these preliminary discussions can therefore be given to trustees at the meeting.

2 The text of a recent letter from Mr. Lewis is reproduced as an addendum (see below section 1).

3 The Birmingham chemistry and physics syllabuses are, on the other hand, generally agreed to be inferior to those of the S.M.A..

F. *Primary school science*

Although most of those interested in science teaching have concentrated on the courses leading to G.C.E., there has also been some consideration of the needs of the primary schools. A recent Ministry of Education pamphlet, *Science in Primary Schools,* was an encouraging move in the right direction; the widely reported British Association Conference on primary school science, held at the end of September 1961, was a further sign of growing public concern.

The difficulties here are serious: any well-qualified teacher will tend to apply for a better-paid post in a public or grammar school, or failing that a comprehensive or secondary modern, with the result that most teachers of 'general science' in primary schools have little or no adequate training in the subject. But it is at this early stage in a child's education that his attitudes are most easily influenced; and a faulty ground-base of understanding may take years to correct it may therefore be held that proper teaching at the primary level is at least as important as a soundly conceived curriculum in later school life.

In the hope that the trustees might be interested in taking the initiative in this field, the assistant directors attended, as observers, the first meeting of an action group at the Royal Institute of Chemistry in October. The group was representative of a wide range of interests, including the professional scientific institutions, university departments of education, teachers' training colleges, local education authorities, the Science Masters' Association, and primary school science teachers. At the end of a lively discussion, it became clear that some positive action might now be taken to improve the situation, and a smaller working committee is to be formed from the original nucleus.

It seems likely that, as soon as any definite proposals have been drawn up, support will be sought from the Foundation. The trustees might therefore like to consider in advance whether they would be favourably disposed towards any well-formulated scheme for the improvement of primary school science teaching, and whether they could, with advantage, influence the planning in any particular direction.

G. *Mathematics*

If the situation in school science at all levels may be admitted to be serious, in mathematics it is critical. But unfortunately, there is no mathematical counterpart to the Science Masters' Association - the Mathematical Association, although worthy and well intentioned, is conservative and cautious in its approach, and is constitutionally precluded from developing a strong central organization.

The teaching crisis in the subject led to an unprecedented conference of university mathematics professors in late September 1961. The proceedings of this conference were not made public, but informal reports have suggested that the reactions of the delegates were in some cases disappointingly complacent. However, some remedial action may perhaps be triggered off by the more lively members of the conference.

In the absence of a strong central lead, there have nevertheless been some discussions of possible curricular reform and some attempts to enliven teaching methods. The latter have been mainly confined to the primary school level, where a number of local education authorities (many of them in conjunction with the National Foundation for Educational Research) have been testing out new methods of teaching mathematical concepts, especially by the use of the Cuisenaire and Stern apparatus. As in early move towards curricular reform, a new 'A' level syllabus was outlined by the Gulbenkian/Birmingham Mathematical Panel; further general discussions at the International Conference produced a handbook, *New Thinking in School Mathematics*. In the spring of 1961 a conference on all aspects of mathematics teaching was held in Southampton, and the proceedings appeared as a lively manifesto, *On Teaching Mathematics*.

The organizer of the Southampton conference, Professor Bryan Thwaites, is at present actively attempting to devise and introduce an alternative G.C.E. course, which would include modem topics such as statistics and set theory, and would reduce the amount of purely manipulative skill required of candidates. His plans involve the collaboration of schoolmasters and university mathematicians in drawing up suitable examination papers, textbooks, and possibly teachers' guides. Professor Thwaites has already approached the Foundation informally for help, and may be submitting a formal application, setting out his scheme in detail, to the next meeting of trustees.

As matters stand this may be the only immediate opportunity for the Foundation to take an active role in mathematics teaching, although work at the primary school level may perhaps also be in need of our support.

H. *Conclusion*.

The preceding sections have concentrated upon the most urgent needs. There are, however, many less pressing but no less important measures which must form part of any comprehensive programme of reform. Such longer-term measures include the provision of well-balanced course for sciences specialists at the sixth-form level, and of suitable science courses for arts sixth-formers; the better integration of advanced school science with first-year university work; a measure of in service retraining for existing science teachers, perhaps by means of holiday refresher courses; a dramatic improvement in the methods of teacher training, with a consequent improvement in general teaching standards at all school levels; and (unless the same situation is to recur periodically with every advance in scientific knowledge) a continuing review of curricula and methods of presentation.

It is thought that the trustees, while considering the more immediate practical steps in some detail, will nevertheless wish to bear these longer-term projects in mind for possible future action.

Appendix III

Lists of Nuffield A-level Physics Trials Schools

A. Trials School 1966-67 - V.J. Long, Organizer

B. 'First' Trials Schools 1968-1971 - Black and Ogborn, Organizers

C. 'Second' Trials Schools 1969-1971 - Black and Ogborn, Organizers

A. Trials School 1966-67 - V.J. Long, Organizer

BARNARD CASTLE SCHOOL Barnard Castle BARNARD CASTLE GRAMMAR/TECHNICAL SCHOOL, Barnard Castle BRIGG GRAMMAR SCHOOL Brigg BROCKENHURST GRAMMAR SCHOOL Brockenhurst ERITH GRAMMAR SCHOOL Erith FOREST HILL SCHOOL London SE23 GAINSBOROUGH ROYAL GRAMMAR SCHOOL Gainsborough HALESOWEN GRAMMAR SCHOOL Halesowen	HILLFOOT HEY HIGH SCHOOL Liverpool HINCKLEY GRAMMAR SCHOOL Hinckley HOLLY LODGE GIRLS'GRAMMAR SCHOOL Smethwick ILKESTON GRAMMAR SCHOOL Ilkeston REPTON SCHOOL Repton RUGBY GIRLS'HIGH SCHOOL Rugby ST JOHN'S SCHOOL Leatherhead

B. 'First' Trials Schools 1968-1971 - Black and Ogborn, Organizers

BANBURYSCHOOL Banbury BARNARD CASTLE SCHOOL Barnard Castle BATLEY GRAMMAR SCHOOL Batley CAMDEN SCHOOL FOR GIRLS London NW5 CRAY VALLEY SCHOOL FOR BOYS Sidcup ELLIOTT SCHOOL London SW15 ERITH SCHOOL Erith FOREST HILL SCHOOL London SE23 GODOLPHIN AND LATYMER SCHOOL London W6 HALESOWEN GRAMMAR SCHOOL Halesowen HINCKLEY GRAMMAR SCHOOL Hinckley HUDDERSFIELD NEW COLLEGE Huddesfield ILKESTON GRAMMAR SCHOOL Ilkeston	KING EDWARD'S CAMP HILL BOYS SCHOOL, Birmingham MALVERN COLLEGE Malvern MILL MOUNT GRAMMAR SCHOOL FOR GIRLS, York MONK'S PARK SCHOOL Bristol NORTH BROMSGROVE HIGH SCHOOL Bromsgrove PARLIAMENT HILL SCHOOL London NW5 REPTON SCHOOL Repton RICKMANSWORTH GRAMMAR SCHOOL Rickmansworth THE SIR FREDERIC OSBORN SCHOOL Welwyn Garden City WOOLVERSTONE HALL SCHOOL Woolverstone CITY OF WORCESTER GRAMMAR SCHOOL FOR GIRLS, Worcester WORCESTER ROYAL GRAMMAR SCHOOL, Worcester

C. 'Second' Trials Schools 1969-1971 - Black and Ogborn, Organizers

ABBEY SCHOOL Ramsey ACKLAM HIGH SCHOOL Acklam BANGOR GRAMMAR SCHOOL Bangor BEECHEN CLIFF SCHOOL Bath BISHOPS STORTFORD SCHOOL Bishops Stortford BLYTH GRAMMAR SCHOOL Blyth BRIGG GRAMMAR SCHOOL Brigg THE CALDER HIGH SCHOOL Halifax CAMPBELL COLLEGE Belfast CHILLINGFORD HIGH SCHOOL Chillingford CHORLTON HIGH SCHOOL Manchester CLIFTON COLLEGE Bristol CROESYCEILIOG GRAMMAR SCHOOL Croesyceiliog CROSS GREEN SCHOOL Leeds DAME ALLAN’S (BOYS) SCHOOL Newcastle-on-Tyne EAST BERKSHIRE COLLEGE OF FE Windsor THE GRAMMAR SCHOOL FOR BOYS Cambridge	THE HARVEY GRAMMAR SCHOOL Folkestone HIGHBURY TECHNICAL COLLEGE Cosham HILLFOOT HEY HIGH SCHOOL Liverpool HINCHINBROOKE SCHOOL Huntingdon HOWELL’S SCHOOL Llandaff KING EDWARD VII SCHOOL Sheffield QUEEN ELIZABETH’S GRAMMAR SCHOOL Gainsborough QUEEN’S SCHOOL Bushey LA RETRAITE HIGH SCHOOL Bristol ROYAL BELFAST ACADEMIC INSTITUTION Belfast RUGBY SCHOOL Rugby ST MALACHY’S COLLEGE Belfast SALE COUNTY GRAMMAR SCHOOL FOR BOYS Sale SURBITON COUNTY GRAMMAR SCHOOL Thames Ditton TEESDALE SCHOOL Barnard Castle WILLIAM ELLIS SCHOOL London NW5

BIBLIOGRAPHY

A. PRIMARY SOURCES:
Archives, personal papers, interviews, communications by letter and telephone

1. Archives:

The Association for Science Education, Hatfield.
Hampshire LEA Archive, Winchester.
King's College, London.
The Nuffield-Chelsea Curriculum Trust, London.
The Nuffield Foundation, London.
The Royal Society, London.
The University of Reading, Bulmershe Court.

2. Personal papers:

Professor L.R.B. Elton, given in trust to K.D. Fuller.
Dr J. Harris, given in trust to K.D. Fuller.
Professor K.W. Keohane, King's College Archive.
Professor Sir N.F. Mott, Cambridge.
Dr J. Spice, Winchester.
Mr E.J. Wenham, given in trust to K.D. Fuller.

3. Interviews:

Profesor P.J. Black, London 4 November 1988.
Professor L.R.B. Elton, Guildford 5 May 1987.
Dr J. Harris, London 5 January 1989.
Profesor P. Kelly, Southampton 1 June 1990.
Profesor K.W. Keohane, Roehampton 27 May 1986.
Profesor Sir N.F. Mott, Cambridge 24 March 1986.
Profesor J. Ogborn, London 15 February 1991.
Mr S. Pascoe, Portsmouth 26 April 1991.
Mr M. Ridley, Egham 1 May 1991.
Dr J. Spice, Winchester 12 July 1988.
Dr M. Waring, Epsom 4 April 1986.
Mr E.J. Wenham, Worcester 4 August 1986.

4. Communications:

Mr W.F. Archenhold, 18 March 1991 and 2 October 1991.
Professor R. Becher, 17 August 1989.
Professor P.J. Black, 22 February 1990.
Professor G. Higginson, 4 September 1989.
Professor K.W. Keohane, 1 February 1990, 2 August 1990.
Professor E.M. Rogers, 16 October, 18 October 1986.
Dr G. van Praagh, 17 August 1989.

Mrs C.M. Wilson, 5 September 1989, 27 July 1990.

File NAP-1 is an assemblage of original memoranda, letters and minutes of meetings drawn from the personal papers of Professor K.W. Keohane and Mr B. Chapman. File NAP-1 mostly deals with the first NAP project Organized by V.J. Long. Reference is also made to a few of the personal communications in this file:

Mr T.M. Auld, 7 August 1981.
Professor P.J. Black, 28 October 1981.
Professor K.W. Keohane, 6 April 1982.
Mr H.B. Lee, 9 October 1981.
Mr R. Parry, 12 March 1982.

This material is held in The Library of The University of Reading at Bulmershe Court.

B. THESES AND DISSERTATIONS:

P.N. ATKINS, An Inquiry into the Aims of, and Obstacles to, A level Science Practical Work as perceived by Teachers in Sixth Form Colleges in England, M.Sc. University of Reading(1987).

K.D. FULLER, Innovation, Institutionalization and Renewal in the Sixth Form curriculum. A History of Nuffield A-Level Physics, Ph.D. University of Reading (1991).

K.D. FULLER, A review of Nuffield 'A' level Physics with particular reference to the historical development and the financial aspects of the project, M.Sc. University of Reading (1982).

J.M. HARDING, Communication and support for change in school science education, Ph.D. University of London (1975).

B.T.W. JAMES, The contribution of the Institute of Physics to education and its influence thereon, M.Ed.(Science Education) University of London (1976).

P.J. KELLY, Curriculum Development and Curriculum Mechanism: An account of the Nuffield A-level Biology Project in relation to the concept of curriculum mechanism, Ph.D. University of London (1971).

W.K.D. MORGAN, The Nuffield A-level Project: A study of the opinions of the pupils following the course in Physics, M.Ed.(Science Education) University of London (1971).

R.B. NICODEMUS, Innovation in Education with special reference to some aspects of the Nuffield Science Teaching Project, Ph.D. University of London (1973).

J.R.L. SWAIN, Evaluation studies on the Nuffield Physical Science Course, Ph.D. University of London (1977).

M. WARING, Aspects of the Dynamics of Curriculum Reform in Secondary School Science, Ph.D. University of London (1975).

C. PUBLISHED SOURCES:

1. Books:

R. ALDRICH and P. GORDON, Dictionary of British Educationalists, University of London Institute of Education (1989).

J. M. ATKIN, The Government in the Classroom, University of London Institute of Education (1980).

T. BECHER and S. MACLURE, The Politics of Curriculum Change, Hutchinson (1978).

P.J. BLACK, The engineering and the humanity of science education. Inaugural lecture 13 December 1977, Chelsea College (1980).

A. BURR (Ed.), Physics at 18+ (Institute of Physics Short Meeting Series No.20), Adam Hilger (1989), Bristol.

B.R. CLARKE (Ed.), The School and the University, University of California Press Ltd. (1985).

R.W. CLARKE, A Biography of the Nuffield Foundation, Longman(1972).

D. COHEN and B.J. FRASER, The Processes of Curriculum Development and Evaluation: A Retrospective Account of the Processes of the Australian Science Education Project, The Curriculum Development Centre (1987), Australia.

L. COHEN, J. THOMAS and L. MANION, Educational Research and Development in Britain 1970-80, NFER-Nelson (1982), Windsor.

DAINTON REPORT, Enquiry into the flow of candidates in Science and Technology into Higher Education, HMSO (1968).

DES, Advancing A levels, Report of a Committee appointed by the Secretary of State for Education and Science and the Secretary of State for Wales, HMSO(1988)

DES, 16-18: The Education and Training of 16-18 year olds, Consultative paper, HMSO (1979).

DES, Broadening A-level Studies. Advanced Supplementary(AS) levels. A guide for schools and colleges, HMSO (1987).

I. GOODSON, School Subjects and Curriculum Change, Croom Helm (1983).

I. GOODSON (Ed.) Social Histories of the Secondary Curriculum: Subjects for Study, The Falmer Press (1985).

I. GOODSON, The Making of the Curriculum: Collected Essays, The Falmer Press (1988).

I.F. GOODSON and R. WALKER, Biography, Identity and Schooling: Episodes in Educational Research, The Falmer Press (1991).

P. GORDON and D. LAWTON, Curriculum Change in the Nineteenth and Twentieth Centuries, Hodder and Stoughton (1978).

H. HAFT and S. HOPMANN, Case Studies in Curriculum Administration History, The Falmer Press (1990).

A. HARRIS, M. LAWN and W. PRESCOTT, Curriculum Innovation, Croom Helm (1975).

HMI, Aspects of Secondary Education in England, HMSO(1979).

M. HOLT, The Tertiary Sector. Education 16-19 in Schools and Colleges, Hodder and Stoughton (1980).

T. HORTON and P. RAGGATT (Eds.), Challenge and Change in the Curriculum, Hodder and Stoughton in association with The Open University (1982).

R. INGLE and A. JENNINGS, Science in Schools: Which Way Now?, University of London Institute of Education (1981).

E.W. JENKINS, From Armstrong to Nuffield. Studies in Twentieth-Century Science Education in England and Wales, John Murray (1979).

B.M. JENNISON and J.OGBORN (Eds), *Wonder and Delight*, Essays in Science Education in honour of the life and work of Eric Rogers 1902-1990, Institute of Physics (1994).

S. JOHNSON, Beloe to Baker: Thirty years of teacher assessment and moderation, Midland Examining Group (1990).

M. KOGAN, The Politics of Educational Change, Manchester University Press (1978).

M. KOGAN, The Politics of Education, Penguin Books (1971).

P.J. KELLY, Science, Life and Education, Inaugural lecture 15 March 1977. Chelsea College, University of London(1978).

J.F. KERR, Practical work in school science, Leicester University Press (1963), Leicester.

J.F. KERR (Ed.), Changing the Curriculum, University of London Press Ltd. (1968).

M. KINGDON, The Reform of Advanced Level, Hodder and Stoughton(1991).

D. LAWTON, Social Change, Educational Theory and Curriculum Planning, Hodder and Stoughton (1973).

D. LAWTON, The Politics of the School Curriculum, Routledge and Kegan Paul (1980).

D. LAWTON, Education, Culture and the National Curriculum, Hodder and Stoughton (1989).

D. LAYTON, Interpreters of Science: A History of the Association for Science Education, John Murray (1985).

J.L. LEWIS (Ed.), Teaching School Physics: a UNESCO source book, Penguin (1972).

G. McCULLOCH, The Secondary Technical School: A Usable Past?, The Falmer Press(1988).

G. McCULLOCH, E. JENKINS, D. LAYTON, Technological Revolution? The Politics of School Science and Technology in England and Wales Since 1945, The Falmer Press (1985).

W.E. MARSDEN (Ed.), Post-War Curriculum Development: An Historical Appraisal, Conference Papers - December 1978, History of Education Society (1979).

N. MOTT, A Life in Science, Taylor and Francis (1986).

NATIONAL CURRICULUM COUNCIL, Core Skills 16-19. A response to the Secretary of State. March 1990, NCC (1990).

NUFFIELD ADVANCED SCIENCE, Biological Science. Teachers' Guide to the Laboratory Guides. Volume I, Penguin Books Ltd. (1970) and Volume II, Penguin Books Ltd. (1971).

NUFFIELD ADVANCED SCIENCE, Chemistry Teachers' Guide I. Topics 1 to 12, Penguin Books Ltd.(1970).

NUFFIELD ADVANCED SCIENCE, Physical Science. Introduction and guide, Penguin Books Ltd.(1973).

NUFFIELD ADVANCED SCIENCE, Physics Teachers' handbook, Penguin Books Ltd.(1971).

J. OGBORN, Voices of Science. An Inaugural lecture, University of London Institute of Education (1985).

J. OLSON (Ed.), Innovation in the Science Curriculum. Classroom Knowledge and Curriculum Change, Croom Helm (1982).

A.D.C. PETERSON, Educating Our Rulers, Duckworth and Co.Ltd.(1957).

A.D.C. PETERSON, The Future of the Sixth Form, Routledge and Kegan Paul (1973).

M. PLASKOW(Ed.), Life and Death of the Schools Council, The Falmer Press (1985).

P. PREECE, The Teaching of Physics. Perspectives 3, University of Exeter (1980).

B.Z. PRESSEISEN, Unlearned Lessons. Current and Past Reforms for School Improvement, The Falmer Press (1985).

P. RAGGATT and G. WEINER (Eds.), Curriculum and Assessment. Some policy issues, The Open University and Pergamon Press (1985), Oxford.

W.A. REID and D.F. WALKER(Eds.), Case Studies in Curriculum Change: Great Britain and the United States, Routledge and Kegan Paul (1975).

REVISED NUFFIELD ADVANCED SCIENCE, Chemistry Teachers' Guide I Topics 1 to 11, Longman Group Limited (1984).

REVISED NUFFIELD ADVANCED SCIENCE, Physics Teachers' Guide I Units A to G, Longman Group Limited (1985).

REVISED NUFFIELD PHYSICS, General Introduction, Longman Group Limited (1977).

E.M. ROGERS, Diffusion of Innovations, The Macmillan Company(1962).

E.M. ROGERS, Physics for the Inquiring Mind. The methods, nature and philosophy of physical science, Princeton University Press (1960).

THE ROYAL SOCIETY, Science Education 11-18 in England and Wales, The Royal Society (1982).

SCHOOLS COUNCIL (1980), see S.D.STEADMAN et al.

SCHOOLS COUNCIL, The first ten years 1964-1974, The Mendip Press (1974), Bath.

SCHOOLS COUNCIL, The Practical Curriculum, Schools Council Working Paper 70, Methuen Educational (1981).

P. SCOTT, The Crisis of the University, Croom Helm (1984).

D. SELA, Teachers' and Students' Reactions to the Revised Nuffield A-level Physics Course (RNAP), Centre for Educational Studies, King's College London(1988).

M.D. SHIPMAN, D. BOLAM and D.R. JENKINS, Inside a curriculum project. A case study in the process of curriculum change, Methuen and Co.Ltd.(1974).

H. SILVER, Education as History, Methuen and Co.Ltd.(1983).

H. SILVER, Education, Change and Policy Process, The Falmer Press (1990).

M. SKILBECK (Ed.) Evaluating the Curriculum in the Eighties, Hodder and Stoughton (1984).

S.D. STEADMAN, C. PARSONS and B.G. SALTER, Impact and Take-up Project. A Second Interim Report to the Schools Council, Schools Council Publications (1980).

L. STENHOUSE, An Introduction to Curriculum Research and Development, Heinemann (1975).

L. STENHOUSE (Ed.), Curriculum Research and Development in Action, Heinemann Educational Ltd. (1980).

R. SUTTON (Ed.), Physics Interface Project. Resource Booklet, University College Cardiff Press (1977), Cardiff.

P.H. TAYLOR (Ed.), Recent Developments in Curriculum Studies, NFER-Nelson (1986), Philadelphia.

P. TAYLOR and J. WALTON (Eds.), The Curriculum: Research, Innovation and Change, Ward Lock Educational (1973).

J.J. THOMPSON (Ed.), Practical Work in Sixth Form Science. Science Centre, University of Oxford (1975), Oxford.

M. WARING, Social pressures and curriculum innovation. A study of the Nuffield Foundation Science Teaching Project, Methuen (1979).

G. WHITTY and M. YOUNG (Eds.), Explorations in the Politics of School Knowledge, Nafferton Books (1976).

S. WILLIAMS, Politics is for People, Penguin Books (1981).

B.E. WOOLNOUGH, Physics Teaching in Schools 1960-85: Of People, Policy and Power, The Falmer Press(1988).

2. Articles:

C.J. ADKINS, A national core syllabus for A-level physics, Phys.Educ., Vol.16, 1981, 128-135.

J.H. AVERY, Book Review. Nuffield Advanced Science: Physics, SSR, Vol.54, 1972, 203-204.

T. BECHER, The Political and Organisational Context of Curriculum Evaluation, in M. SKILBECK (Ed.),Evaluating the Curriculum in the Eighties. Hodder and Stoughton(1984), pp.100-109.

R. BIENIEK, Evolution of the Two Cultures controversy, Am.J.Phys., Vol.49, 1981, 417-423.

P.J. BLACK, Pupils' attitudes to science, Studies in Science Education, Vol.4, 1977, 149-153.

P.J. BLACK, Revolution in Sixth Form Studies, Phys.Bull., Vol.29, 1978, 223-225.

P.J. BLACK and J.M.OGBORN, The Nuffield Advanced Physics Course, Phys.Bull., Vol.21, 1970, 301-303.

P.J. BLACK and J. OGBORN, The Nuffield Physicist in the university, Phys.Educ., Vol.7, 1972, 66-70.

P.J .BLACK and J.M. OGBORN, The Nuffield A-level physics examination, Phys.Educ., Vol.12, 1977, 12-16.

N. BOOTH, The Impact of Science Teaching Projects on Secondary Education, Educ.in Sc., 63, 1975, 27-30.

H.F. BOULIND, The Nuffield Foundation Science Teaching Project XI: O-level physics examinations, SSR, Vol.49, 1968, 670-678.

H. BRADLEY, A Survey of Science Teaching in Secondary Schools, The University of Nottingham School of Education(1976).

J.K. BRIERLEY, Biology and the education of the sixth former, SSR, Vol.XLIV, 1963, 376-384.

S.A. BROWN, A Review of the Meanings of, and Arguments for, Integrated Science, Studies in Science Education, Vol.4, 1977, 31-62.

T.G.K. BRYCE and I.J. ROBERTSON, What can they do? A review of practical assessment in Science, Studies in Science Education, Vol.12, 1985, 1-24.

J.G. BUCKLEY and R.F. KEMPA, Practical work in sixth-form chemistry courses, SSR, Vol.53, 1971, 24-36.

T. CARRICK, Some biology teachers' goals for Advanced level teaching, J.of Bio.Educ., Vol.17, 1983, 205-213.

R.G. CAWTHORNE, Nuffield Advanced Physics, Phy.Bull., Vol.21, 1970, p.564.

K. CHARLTON, The Contribution of History to the Study of the Curriculum, in J.F.KERR(Ed.), Changing the Curriculum, University of London Press Ltd.(1968), pp.63-78.

G. COOK, Teaching styles in the Nuffield A-level Physics Course, SSR, Vol.60, 1978, 348-350.

E.H. COULSON, A-level Chemistry, Educ.in Chem., Vol.6, 1969, 200-202.

E.H. COULSON, Nuffield Advanced Science - Chemistry. An account of a stewardship. SSR, Vol.52, 1970, 261-271.

J.R. CRELLIN, R.J.J. ORTON and D.A. TAWNEY, Present-day school physics syllabuses, Rep.Prog.Phys., Vol.42, 1979, 677-725.

P. D'ARCY, Curriculum change: product or process? in M. GALTON (Ed.), Curriculum Change. The lessons of a decade, Leicester University Press(1980), pp.95-105.

K. DOBSON, Still investigating: twenty years of Nuffield A-level Physics investigations, Phys.Educ., Vol.23, 1988, 337-340.

W.H. DOWDESWELL, Some aspects of science teaching in the United States, SSR, Vol.XLII, 1960, 26-41.

W.H. DOWDESWELL, The Nuffield Project I: Biology 11-16, SSR, Vol.XLVIII, 1967, 323-331.

W.H. DOWDESWELL, Curriculum: a new phase of evolution?, SSR, Vol.59, 1977, 374-376.

J.F. EGGELSTON and P.J. KELLY, The Assessment of Project Work in A-level Biology, Educational Research, Vol.12, 1970, 225-229.

L.R.B. ELTON, Assessment for Learning, in D. BLIGH (Ed.), Professionalism and flexibility in learning. Society for Research into Higher Education (1982),pp.106-135.

M. ERAUT, Nuffield Science, J.Curriculum Studies, Vol.11, 1979, 341-358.

M. ERAUT, Some recent evaluation studies of curriculum projects - a review in D.TAWNEY(Ed.) Curriculum Evaluation Today: Trends and Implication, Schools Council Research Studies (1976), pp.102-124.

P.J. FENSHAM, The Time Factor in Curriculum Development, J.Curriculum Studies, Vol.3, 1971, 179-183.

P.J. FENSHAM, Science curricula and the Organisation of Secondary Schooling, J.Curriculum Studies, Vol.6, 1974, 61-72.

G.E. FOXCROFT, Electronics in the Nuffield advanced physics course, Phys.Educ., Vol.7, 1972, 14-20.

G.E. FOXCROFT, From levers to computers: Recent Advances in the Teaching of Physics, Proc.Roy.Instn.Gt.Br., Vol.48, 1975, 157-171.

B.M. FRANKLIN, Curriculum History: Its Nature and Boundaries, Curriculum Inquiry, Vol.7, 1977, 67-79.

K.D. FULLER and D.D. MALVERN, One Don, One Beak - University pressure and curriculum development in the first Nuffield A-level physics project, British Journal of Educational Studies, Vol.32, No.1, 1986, 220-234.

I. GOODSON, Subjects for Study: Aspects of a Social History of Curriculum, J.Curriculum Studies, Vol.15, 1983, 391-408.

I.F. GOODSON, Studying curriculum: towards a social constructionist perspective, J.Curriculum Studies, Vol.22, 1990, 299-312.

C.D. GOULD, The impact of Nuffield O-level Biology - an agent of change in biology teaching?, J.of Bio.Educ., Vol.17, 1983, 201-204.

H.F. HALLIWELL and G. VAN PRAAGH, The Nuffield Foundation Science Teaching Project - II: Chemistry 11-16, SSR, Vol.XLVIII, 1967, 332-336.

D. HAMILTON, Nuffield O-level sciences: Sources or courses?, SSR, Vol.51, 1970, 905-911.

J.M. HARDING, P.J. KELLY and R.B. NICODEMUS, The Study of Curriculum Change, Studies in Science Education, Vol.3, 1976, 1-30.

J. HARGREAVES and T. HARGREAVES, Some Models of School Science in British Curriculum Projects, and their Implications for STS Teaching at the Secondary Level, Social Studies of Science, Vol. 13, 1983, 569-604.

J. HARRIS, Revised Nuffield Advanced Physics, Phys.Educ., Vol.20, 1985, 18-23.

J.S. HAZLETT, Conceptions of Curriculum History, Curriculum Inquiry, Vol.9, 1979, 129-135.

J.O. HEAD, Nuffield A-levels and undergraduate performance, SSR, Vol.6, 1975, 601-604.

R.B. INGLE and E. COULSON, The Revision of Nuffield O-level Chemistry, Educ.in Sc., No.61, 1975, 15-17.

A. JACKSON, In Defence of Nuffield, Educ.in Chem., Vol.4, 1967, 64-67.

R. JAKEWAYS, Assessment of A-level Physics (Nuffield) Investigations, Phys.Educ., Vol.21, 1986, 212-216.

T. JANSEN and R. van der VEGT, On lasting innovation in schools: beyond institutionalization, J.Education Policy, Vol.6, 1991, 33-46.

P. KELLY, The Biological Sciences Curriculum Study, SSR, Vol.XLIV, 1963, 312-323.

P.J. KELLY, Implications of Nuffield A-level biological science, SSR, Vol.52, 1970, 272-285.

P.J. KELLY, From innovation to adaptability: the changing perspective of curriculum development, in M. GALTON (Ed.), Curriculum Change. The lessons of a decade, Leicester University Press (1980), Leicester, pp.65-80.

P.J. KELLY and W.H. DOWDESWELL, The Nuffield A-level Biological Science Project, J.Biol.Educ., Vol.4, 1970, p.4.

P.J. KELLY and G. MONGER, An evaluation of the Nuffield O-level biology course materials and their use Part I, SSR, Vol.55, 1974, 470-482; Part II, SSR, Vol.55, 1974, 705-715.

P. KELLY AND I. ROLLS, Non-specialist courses in science for sixth forms, SSR, Vol.XXXIX, 1958, 222-233.

K.W. KEOHANE, New science and old cultures, Phys.Educ., Vol.11, 1976, 16-18.

J. KERR, The control of change, SSR, Vol.58, 1977, 625-634.

D. LAWTON, 100 Years of Curriculum Change, in Trends in Education, 1870-1970, Department of Education and Science, HMSO(1970) pp.18-26.

D. LAYTON, The secondary school curriculum and science education, Phys.Educ., Vol.8, 1973, 19-23.

J.R. LEECE AND J.C. MATHEWS, Nuffield Advanced Chemistry Research Project. Casting the net wider: questionnaires and other sources of information, SSR, Vol.58, 1976, 342-350.

J.L. LEWIS, Books for Nuffield A-level physics, Phys.Educ., Vol.10, 1975, 74-76.

J.L. LEWIS, A Nuffield view of Physics, Phys.Educ., March 1977, 70-73.

R.E. LISTER, The aims of questions in A-level biology examinations, SSR, 1969, 514-527.

R. LOCK, A history of practical work in school science and its assessment, 1860-1886, SSR, 70, 1988, 115-119.

G. McCULLOCH, A Technocratic Vision: The Ideology of School Science Reform in Britain in the 1950s, Social Studies of Science, Vol. 18, 1988, 703-724.

G. McCULLOCH, Friends and innocents: in search of the physics curriculum, Studies in Science Education, Vol.15, 1988, 128-132.

M. MADEN, The school and the university. England and Wales, in B.R. CLARKE(Ed.), The School and the University, University of California Press Ltd (1985), pp.77-102.

J.C. MATHEWS and J.R. LEECE, Nuffield Advanced Chemistry: the free response questions and assessment of practical work, SSR, Vol.57, 1975, 362-367.

J.C. MATHEWS and J.R. LEECE, Nuffield Advanced Chemistry Research Project: reporting and using examination outcomes, SSR, Vol.58, 1977, 546-552.

A.E.E. McKENZIE, The Future of the Nuffield Science Teaching Project at O-level, Educ.in Sc., No.33, 1969, 24-26.

H. MISSELBROOK, The Nuffield Foundation Science Teaching Project VIII: Science in secondary schools, SSR, Vol.49, 1968, 334-341.

G. MONGER, The Revision of Nuffield O-level Biology, Educ.in Sc., No.64, 1975, 17-18.

J. MORRIS, 16 to 19 - a menu of opportunity, SSR, Vol.71, 1990, 9-18.

R.B. NICODEMUS, Discrepancies in Measuring Adoption of New Curriculum Projects, Educ.in Sci., Vol.65, 1975, 26-28.

R.B. NICODEMUS and D. MARSHALL, Familiarity of Headteachers with Twenty-five New Curriculum Projects, Educational Studies, Vol.1, 1975, 191-200.

H. NIELSON and P. THOMSEN, Crisis in physics education, in P.V. THOMSEN (Ed.), Science Education and the History of Physics, proceedings of the multi-national teacher/teacher training conference, Deutches Museum, Munich, 3-9 May, 1986, pp.9-23.

R. NYHOLM, School Science - Education, Preparation or Indoctrination?, SSR, Vol.49, 1968, 659-669.

R.S. NYHOLM, Education for Change, J.of Chem.Educ., Vol.48, 1971, 34-38.

J. OGBORN, Introducing quantum physics, Phys.Educ., Vol.9, 1974, 436-443.

J. OGBORN, The second law of thermodynamics: a teaching problem and an opportunity, SSR, Vol.57, 1976, 654-672.

J. OGBORN, Decisions in curriculum development - a personal view, Phys.Educ., Vol.13, 1978, 11-18.

J. OGBORN, Modern physics curricula in higher education, Rep.Prog.Phys., Vol.42, 1979, 727-772.

F. OLDHAM, University Reactions to Changes in School Physics Teaching, Contemporary Physics, Vol.5, Oct.1963-Aug.1964, 302-303.

A.W. PELL, Subject swings at A-level: attitudes to physics, SSR, Vol.58, 1977, 763-770.

A.W. PELL, Enjoyment and Attainment in Secondary School Physics, Br.Educ.Research Journal, Vol.11, 1985, 123-132.

A.D.C. PETERSON, Three Decades of Non-reform, Oxford Review of Education, Vol.14, 1988, 127-137.

M. POPE and P. DENICOLO, Intuitive Theories - a Researcher's Dilemma: some practical methodological implications, British Educational Research Journal, Vol.12, 1986, 153-165.

B.J. PURVIS, A case for the adoption of Nuffield A-level Biological Science, SSR, Vol.58, 1977, 774-780.

D. RAFFE, The Content and Context of Educational Reform, in P. RAGGATT and G, WEINER(Eds.), Curriculum and Assessment. Some policy issues, The Open University and Pergamon Press (1985), Oxford, pp.67-73.

J.A. REANEY, Specialization in sixth form science - the N and F evidence, SSR, Vol.60, 1978, 357-359.

W. REID, Curriculum theory and curriculum change: What can we learn from history? J.Curriculum Studies, Vol.18, No.2, 1986, 159-166.

W.A. REID, Strange curricula: origins and development of the institutional categories of schooling, J.Curriculum Studies, Vol.22, 1990, 203-216.

M.B. RIDLEY, An investigation into the attitudes at universities towards Nuffield and traditional A-level physics, SSR, Vol.63, 1982, 556-557.

I. ROBERTS and C. TERRY, The Teaching of the Physical Sciences, in L. COHEN, J. THOMAS, L. MANION, Educational Research and Development in Britain 1970-1980, NFER - Nelson (1982), Windsor, pp.407-419.

SCHOOLS COUNCIL, Nuffield Foundation Science Teaching Project: survey of adoption by schools and support by Local Education Authorities, Educ.in Sc., 32, 1969, 20-23.

SISTER ST JOAN OF ARC, An Enquiry into the Teaching of Physical Science in Girls' Grammar Schools, Contemporary Physics, Vol.4, 1962-63, 371-389.

STANDING CONFERENCE OF PROFESSORS OF PHYSICS, A university view on a possible minimum core syllabus for sixth-form physics, Phys.Educ., Vol.13, 1978, 255-258.

L. STENHOUSE, What counts as research?, Br.J.of Educ.Studs., Vol.29, 1981, 103-113.

O.M. STEPAN and J.M. OSBORNE, The Nuffield Foundation Science Teaching Project V: physics apparatus and laboratory design, SSR, Vol.48, 1967, 676-684.

P. STEVENS, On the Nuffield Philosophy of Science, J.of Philosophy of Education, Vol.12, 1978, 99-110.

G. TALL, British Science Curriculum Projects -How Have They Taken Root in Schools?, Eur.J.Sci.Educ., Vol.3, 1981, 17-38.

P.H. TAYLOR, Curriculum Research: Retrospect and Prospect - a Personal Appreciation, J.Curriculum Studies, Vol.14, 1982, 53-59.

M.J. TEBBUTT, The Growth and Eventual Impact of Curriculum Development Projects in Science and Mathematics, J.of Curriculum Studies, Vol.10, 1978, 61-73.

M.J. TEBBUTT, Teachers' Views about the Nuffield advanced physics course, Phys.Educ., Vol.16, 1981, 228-233.

K. THOMAS, School Physics for the 1980's, Phys.Bull., Vol.28, 1977, 100-101.

J.J. THOMPSON, The Place of Science in a Broadly Based 16-19 Curriculum, Educ.in Sc., No.77, 1978, 18-20.

A. TODD, The Scientist - Supply and Demand, SSR, Vol.XXXVIII, 1957, 160-167.

A.W. TROTTER, Project work in Physics Education, in J.G.J ONES and J.L. LEWIS(Eds.), The Role of the Laboratory in Physics Education, John Goodman and Sons (1978), pp.105-117.

G. VAN PRAAGH (Ed.), H.E.Armstrong and Science Education. John Murray (1973), pp. 60-80.

M. VOKINS, Nuffield and N & F, Educ.in Chem., Vol.13, 1976, 173-174.

M. WARING, Background to Nuffield Science, History of Education, Vol.8, No.3, 1979, 223- 237.

M. WARING, The Implementation of Curriculum Change in School Science in England and Wales, Eur.J.Sci.Educ., Vol.1, 1979, 257-275.

M. WARING, How do you change what happens in schools?, in P. ADEY (Ed.), Innovation in Science Education: UK-Japan Seminar, University of London 8-12 September 1980, The British Council(1980).

E.J. WENHAM, The Nuffield Foundation Science Teaching Project - III: Physics 11 - 16, SSR, Vol.48, 1967, 337-346.

B.E. WOOLNOUGH, Changes in Physics Teaching in England since 1960: The People, Policies and Power in Curriculum Administration, found in H.HAFT and S.HOPMANN(Eds.), Case Studies in Curriculum Administration History, The Falmer Press(1990), pp.125-139.

M.F.D. YOUNG, The social responsibility of the physicist, Phys.Educ., Vol.11, 1976, 498- 503.